LEEDS PHILOSOPHICAL
AND LITERARY SOCIETY.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LVIII. FEBRUARY 11, 1898. No. 4

Sir R. S. Ball, LL.D., F.R.S., President, in the Chair.

Samuel Cooke, M.A., Principal of the College of Science, Poona, India ;

Thomas Charlton Hudson, B.A., Nautical Almanac Office, 3 Verulam Buildings, Gray's Inn, W.C., and 83 Dresden Road, Upper Holloway, N ;

David Hunter, John O'Groats Villa, Cambuslang, Glasgow ;

Edmund Taylor Whittaker, B.A., Trinity College, Cambridge ; and

Walter Wickham, Radcliffe Observatory, and 62 St. John's Road, Oxford,

were balloted for and duly elected Fellows of the Society.

The following Candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

Captain Vernon L. D. Broughton, Hillside, South Godstone, Surrey (proposed by Duncan Forbes) ;

Charles Friswell, 34 Madeley Road, Ealing, W. (proposed by J. McCarthy) ;

Professor C. J. Joly, M.A., Royal Astronomer of Ireland, the Observatory, Dunsink, co. Dublin (proposed by A. A. Rambaut) ; and

William Ritchie, Mathematical and Science Teacher, 75 Morningside Road, Edinburgh (proposed by William Peck).

Report of the Council to the Seventy-eighth Annual General Meeting of the Society.

The following table shows the progress and present state of the Society :—

	Compounders	Annual Subscribers	Total Fellows	Associates	Patron	Grand Total
1896 December 31	253	391	644	40	1	685
Since elected	+ 3	+18	...	...	...	...
Deceased	−14	−10	...	−2	...	...
Resigned	...	− 7	...	...	...	...
Removals	+2	− 2	...	...	...	...
Expelled	...	− 3	...	...	...	...
1897 December 31	244	387	631	38	1	670

Mr. Knobel's Account as Treasurer of the Royal

RECEIPTS.

	£ s. d.	£ s. d.
Balances, 1897 January 1:—		
At Bankers'	186 12 1	
In hand of Assistant Secretary on account of Turnor and Horrox Fund	14 13 1	
In hand of Assistant Secretary on Petty Cash Account	0 12 4	
		201 17 6
Dividends on £13,200 Consols, 2¾ per cent. ...	350 18 4	
1 quarter's dividend on £900 New 2½-per-cent. Stock	5 8 9	
3 quarters' dividends on £932 19 0 Metropolitan 2½-per-cent. Stock	16 18 3	
Dividends on £1,250 Metropolitan 3-per-cent Stock	36 5 0	
		409 10 4
Received on account of Subscriptions:—		
Arrears	153 6 0	
Annual Contributions for 1897	600 12 0	
„ „ 1898	6 6 0	
Admission Fees	46 4 0	
First Contributions	31 10 0	
		837 18 0
Composition Fees		105 0 0
Sales of Publications:—		
At Williams and Norgate's, 1896	34 5 7	
At Society's Rooms, 1897	60 13 9	
Sale of Photographs, 1897	16 12 0	
		111 11 4
Sale of £900 New 2½-per-cent. Stock	...	952 16 6
Income Tax refunded by Commissioners of Inland Revenue		14 1 8
Outstanding Cheques		6 12 0
		£2,639 7 4

Astronomical Society, from 1897 *January* 1 *to December* 31.

EXPENDITURE.

	£	s.	d.	£	s.	d.
Assistant Secretary: Salary	250	0	0			
„ „ for assistance in editing Society's Publications ...	50	0	0			
				300	0	0
House Duty	2	12	6			
Fire Insurance	7	16	6			
				10	9	0
Printing, &c., *Monthly Notices*	464	8	3			
„ List of Fellows	7	7	0			
„ Miscellaneous	23	1	0			
Lithography, Engraving, etc.	17	11	6			
				512	7	9
Reproduction of Photographs (Photographic Comm.)				18	13	8
Purchase of Photographs	3	12	0			
Turnor and Horrox Fund: Purchases for Library	27	3	11			
Binding Books in Library	15	14	9			
				46	10	8
Alterations and repairs to the Waters Telescope ...				18	2	1
Clerk's Wages	52	0	0			
Postage and Telegrams	74	12	9			
Carriage of Parcels	3	15	0			
Stationery and Office Expenses	3	16	7			
Ditto Spottiswoode & Co.	9	10	6			
				143	14	10
Expenses of Meetings	21	0	0			
Lantern Expenses	8	14	0			
				29	14	0
House Expenses	63	6	4			
Coals and Gas	51	12	10			
Electric Light Expenses	6	9	4			
Time Signal	6	10	0			
Sundry Fittings and Repairs	12	9	9			
Sundries	5	17	4			
				146	5	7
Haden & Son, new heating boiler, etc.				115	12	4
Illuminating address...	4	15	0			
A. Wyon, 5 Gold Medals	52	10	0			
				57	5	0
Jackson Gwilt Fund: 5 Bronze Medals, etc. ...	12	2	0			
„ „ Grant to Lewis Swift ...	25	0	0			
				37	2	0
Lee and Janson Fund Grant				5	0	0
Deductions on Cheques	0	1	11			
Cost of power of attorney	0	11	6			
Cost of American draft	0	1	0			
Cheque book	0	8	4			
				1	2	9
Purchase of £932 19 0 Metropolitan 2½-per-cent. Stock				952	16	6
Balances, 1897 December 31:—						
At Bankers'	239	1	9			
In hand of Assistant Secretary on account of Turnor and Horrox Fund	5	9	2			
In hand of Assistant Secretary on Petty Cash Account	0	0	3			
				244	11	2
				£2,639	7	4

Report of the Auditors.

We have examined the Treasurer's accounts for the year 1897, and have found and certified the same to be correct. The cash in hand on December 31, 1897, including the balance at the bankers', &c., amounted to £244 11*s.* 2*d.*

The funded property of the Society is the same as at the end of last year, except that £900 2½ per cent. Consols have been sold, and £932 19*s.* Metropolitan 2½ per cent. stock has been bought with the proceeds.

The books, instruments, and other effects in the possession of the Society have been examined, and they appear to be in a satisfactory condition.

We have laid on the table a list of the names of those Fellows who are in arrear for sums due at the last Annual General Meeting of the Society, with the amount due against each Fellow's name.

(Signed) RICHARD INWARDS,
F. W. LEVANDER,
A. C. D. CROMMELIN.

1898 *February* 2.

Trust Funds.

The Turnor Fund: A sum of £450 2¾-per-cent. Consols, the interest to be used in the purchase of books for the Library.

The Horrox Memorial Fund: A sum of £100 2¾-per-cent. Consols, the interest to be used in the purchase of books for the Library.

The Lee and Janson Fund: A sum of £323 16*s.* 6*d.* 2¾-per-cent. Consols, the interest to be given by the Council to the widow or orphan of any deceased Fellow or Associate of the Society who may stand in need of it.

The Hannah Jackson (née Gwilt) Fund: A sum of £300 2¾-per-cent. Consols, the interest to be given in Medals or other awards, in accordance with the terms of the Trust.

Assets and Present Property of the Society, 1898 January 1.

	£ s. d.	£ s. d.
Balances, 1897 December 31:—		
At Bankers'	239 1 9	
In hand of Assistant Secretary on account of Turnor and Horrox Fund	5 9 2	
In hand of Assistant Secretary on Petty Cash Account	0 0 3	
	244 11 2	
Less outstanding cheques	6 12 0	
		237 19 2
Due on account of Subscriptions:—		
2 Contributions of 4 years' standing... ...	16 16 0	
16 „ 3 „	100 16 0	
31 „ 2 „	130 4 0	
58 „ 1 „	121 16 0	
1 Admission Fee and First Contribution ...	3 3 0	
	372 15 0	
Less 3 Contributions for 1898 paid in advance	6 6 0	
		366 9 0
Due from Messrs. Williams and Norgate for sales of Publications during 1897		1 13 1

£13,200 $2\frac{3}{4}$-per-cent. Consols, including the Lee and Janson Fund, the Turnor and Horrox Fund, and the Jackson-Gwilt Fund.

£1,250 Metropolitan 3-per-cent. Stock.

£932 19 0 Metropolitan $2\frac{1}{2}$-per-cent. Stock.

Astronomical and other Manuscripts, Books, Prints, and Instruments.

Furniture, &c.

Stock of Publications of the Society.

Four Gold Medals.

Stock in hand of volumes of the *Memoirs*:—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I. Part 1	7	...	XXX.	149	1
I. Part 2	41	...	XXXI.	135	...
II. Part 1	50	3	XXXII.	146	...
II. Part 2	15	3	XXXIII.	155	...
III. Part 1	64	1	XXXIV.	158	1
III. Part 2	82	1	XXXV.	104	2
IV. Part 1	76	3	XXXVI.	187	8
IV. Part 2	89	3	XXXVII. Part 1	332	7
V.	100	3	XXXVII. Part 2	278	8
VI.	117	6	XXXVIII.	263	1
VII.	140	3	XXXIX. Part 1	228	3
VIII.	124	3	XXXIX. Part 2	233	3
IX.	131	3	XL.	248	1
X.	143	...	XLI.	395	1
XI.	150	...	XLII.	224	3
XII.	156	...	XLIII.	225	...
XIII.	154	...	XLIV.	206	1
XIV.	362	...	XLV.	238	...
XV.	135	...	XLVI.	217	1
XVI.	159	1	XLVII. Part 1	3	...
XVII.	142	1	XLVII. Part 2	18	...
XVIII.	136	1	XLVII. Part 3	2	...
XIX.	146	...	XLVII. Part 4	10	...
XX.	135	1	XLVII. Part 5	8	...
XXI. Part 1	310	...	XLVII. Part 6	9	...
XXI. Part 2	98	...	XLVII.	190	...
XXI. 1 & 2 (together)	57	...	XLVIII. Pt. 1	241	...
XXII.	159	1	XLVIII. Pt. 2	233	1
XXIII.	143	...	XLIX. Part 1	378	1
XXIV.	150	1	XLIX. Part 2	258	1
XXV.	160	...	L.	248	1
XXVI.	166	1	LI.	310	1
XXVII.	418	1	Index to *Memoirs*	619	3
XXVIII.	376	...			
XXIX.	397	1			

Stock in hand of volumes of the *Monthly Notices*:—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I.	54	...	XXXI.	91	...
II.	58	...	XXXII.	108	5
III.	...	...	XXXIII.	90	...
IV.	...	...	XXXIV.	68	1
V.	...	...	XXXV.	52	...
VI.	42	...	XXXVI.	26	1
VII.	2	...	XXXVII.	33	3
VIII.	153	2	XXXVIII.	96	2
IX.	24	3	XXXIX.	93	...
X.	172	1	XL.	105	3
XI.	184	...	XLI.	105	5
XII.	106	2	XLII.	113	1
XIII.	177	2	XLIII.	111	2
XIV.	176	3	XLIV.	114	2
XV.	167	2	XLV.	115	1
XVI.	154	1	XLVI.	110	...
XVII.	167	1	XLVII.	127	2
XVIII.	242	...	XLVIII.	117	1
XIX.	52	...	XLIX.	112	8
XX.	31	...	L.	111	10
XXI.	16	...	LI.	114	8
XXII.	30	...	LII.	114	12
XXIII.	17	...	LIII.	115	15
XXIV.	22	...	LIV.	115	16
XXV.	13	...	LV.	129	3
XXVI.	9	1	LVI.	133	6
XXVII.	3	...	LVII.	136	8
XXVIII.	70	...	1st Index ...	548	3
XXIX.	50	...	2nd „ ...	845	...
XXX.	62	2			
LIBRARY CATALOGUE				546	2

In addition to the above volumes of the *Monthly Notices*, the Society has a considerable stock of separate numbers of nearly all the volumes. With the exception, however, of Vols. XXXVI. to LVII., no complete volumes can be formed from the separate numbers in stock.

Instruments belonging to the Society.

A brief description of the chief instruments and other particulars relating to them will be found in *Monthly Notices*, vol. xxxvi. p. 126.

No. 1. The *Harrison* clock.
„ 2. The *Owen* portable circles, by Jones.
„ 3. The *Beaufoy* circle.
„ 4. The *Beaufoy* transit instrument.
„ 5. The *Herschel* 7-foot telescope.
„ 6. The *Greig* universal instrument, by Reichenbach and Ertel. The transit telescope, by Utzschneider and Fraunhofer, of Munich.
„ 7. The *Smeaton* equatorial.
„ 8. The *Cavendish* apparatus.
„ 9. The 7-foot Gregorian telescope (late Mr. Shearman's).
„ 10. The variation transit instrument (late Mr. Shearman's).
„ 11. The universal quadrat, by Abraham Sharp.
„ 12. The *Fuller* theodolite.
„ 13. The standard scale, by Troughton and Simms.
„ 14. The *Beaufoy* clock, No. 1.
„ 15. The *Beaufoy* clock, No. 2.
„ 16. The *Wollaston* telescope.
„ 17. The *Lee* circle.
„ 18. The *Sharpe* reflecting circle.
„ 19. The *Brisbane* circle.
„ 20. The *Baker* universal equatorial.
„ 21. The *Reade* transit.
„ 22. The *Matthew* equatorial, by Cooke.
„ 23. The *Matthew* transit instrument.
„ 24. The *South* transit instrument.
„ 25. A sextant, by Bird (formerly belonging to Captain Cook).
„ 26. A globe showing the precession of the equinoxes.
The *Sheepshanks* collection :—
„ 27. (1) 30-inch transit instrument, by Simms, with level and two iron stands.
„ 28. (2) 6-inch transit theodolite, with circles divided on silver; reading microscopes, both for altitude and azimuth; cross and siding levels; magnetic needle; plumb-line; portable clamping foot and tripod stand.

No. 29. (3) Equatorial stand and clock movement for $4\frac{6}{10}$-inch telescope (telescope lost); double-image micrometer; two wire micrometers; object-glass micrometer.

„ 30. (4) $3\frac{1}{4}$-inch achromatic telescope, with equatorial stand; double-image micrometer; one terrestrial and three astronomical eyepieces.

„ 31. (5) $2\frac{3}{4}$-inch achromatic telescope, with stand; one terrestrial and three astronomical eyepieces.

„ 33. (7) 2-foot navy telescope.

„ 34. (8) Transit instrument of 45 inches focal length, with iron stand and also Y's for fixing to stone piers; two axis levels.

„ 35. (9) Repeating theodolite, by Ertel, with folding tripod stand.

„ 36. (10) 8-inch pillar sextant, by Troughton, divided on platinum, with counterpoise stand and artificial horizon.

„ 37. (11) Portable zenith telescope and stand, $2\frac{3}{4}$-inch aperture and 26 inches focal length; 10-inch horizontal circle and 8-inch vertical circle, reading to 10″ by two verniers to each circle.

„ 38. (12) 18-inch Borda repeating circle, by Troughton, $2\frac{1}{8}$-inch aperture and 24 inches focal length; the circles divided on silver, the horizontal circle being read by four verniers, and the vertical circle by three verniers, each to 10″.

„ 39. (13) 8-inch vertical repeating circle, with diagonal telescope, by Troughton and Simms; circle divided on silver, reading to 10″; a 5-inch circle at eye-end, reading to single minutes; horizontal circle 9 inches diameter in brass to single minutes.

„ 40. (14) A set of surveying instruments, consisting of a 12-inch theodolite for horizontal angles only, reading to 10″; two sets of adjusting plates; tripod stand with enclosed telescope; heavy stand for theodolite; Y-piece of level; two large and three small ground-glass bubbles divided; level collimator, object-glass $1\frac{5}{8}$-inch diameter and 16 inches focal length; micrometer eyepiece, comb, and wires; mercury bottle and trough.

„ 41. (15) Level collimator, with object-glass $1\frac{7}{8}$-inch diameter and 16 inches focal length; stand, rider-level, and fittings.

„ 42. (16) 10-inch reflecting circle by Troughton, reading by three verniers to 20″; counterpoise stand; artificial horizon, with mercury; two tripod stands.

„ 43. (17) Hassler's reflecting circle, by Troughton, with counterpoise stand.

„ 44. (18) 6-inch reflecting and repeating circle, by Troughton and Simms, contained in three boxes, two of which form stands. Circle divided on silver, reading to single

minutes ; two inside arcs divided to single degrees, 150 degrees on each side ; artificial horizon and mercury.

No. 45. (19) 5-inch reflecting and repeating circle, by Lenoir, of Paris.

„ 46. (20) Reflecting circle, by Jecker, of Paris, 11 inches in diameter, with one vernier reading to 15″.

„ 47. (21) Box sextant ; reflecting plane and level.

„ 48. (22) Prismatic compass, by Troughton and Simms.

„ 49. (23) Mountain barometer.

„ 50. (24) Prismatic compass, by Thomas Jones, mounted with a cylindrical lens.

„ 51. (25) Ordinary $4\frac{1}{2}$-inch compass with needle.

„ 52. (26) Dipping needle, by Robinson.

„ 53. (27) Compass needle, mounted for variation.

„ 54. (28) Magnetic intensity needle, by Meyerstein, of Göttingen ; a strongly fitted brass box with heavy magnet ; filar suspension.

„ 55. (29) Box of magnetic apparatus.

„ 56. (30) Hassler's reflecting circle, by Troughton ; a $10\frac{1}{2}$-inch reflecting and repeating circle, with stand and counterpoise, divided on platinum with two movable and two fixed indices ; four verniers reading to 10″.

„ 57. (31) Box sextant and glass plane artificial horizon, by Troughton and Simms.

„ 58. (32) Plane $2\frac{3}{8}$-inch speculum, artificial horizon and stand.

„ 59. (33) $2\frac{1}{2}$-inch circular level horizon, by Dollond.

„ 60. (34) Artificial horizon, roof, and trough ; the trough $8\frac{1}{4}$ by $4\frac{1}{2}$ inches ; tripod stand.

„ 61. (35) Set of drawing instruments, consisting of 6-inch circular protractor and common protractor, T-square ; one beam compass.

„ 62. (36) A pantograph.

„ 63. (37) A noddy.

„ 64. (38) A small Galilean telescope with object-glass of rock crystal.

„ 65. (39) Five levels.

„ 66. (40) 18-inch celestial globe.

„ 67. (41) Varley stand for telescope.

„ 69. (43) Telescope, with object-glass of rock crystal.

„ 71. Portable altazimuth tripod.

„ 72. Four polarimeters.

„ 74. Registering spectroscope, with one large prism.

„ 76. Two five-prism direct-vision spectroscopes.

„ 78. $9\frac{1}{4}$-inch silvered-glass reflector and stand, by Browning.

„ 79. Spectroscope.

„ 80. A small box, containing three square-headed Nicol's prisms ; two Babinet's compensators ; two double-image prisms ; three Savarts ; one positive eyepiece, with Nicol's prism ; one dark wedge.

No. 81. A back-staff, or Davis' quadrant.
„ 82. A nocturnal or star dial.
„ 83. An early non-achromatic telescope, of about 3 feet focal length, in oak tube, by Samuel Scatliffe, London.
„ 84. A Hollis observing chair.
„ 85. Double-image micrometer, by Troughton and Simms.
„ 86. $4\frac{1}{2}$-inch Gregorian reflecting telescope, by Short, with altazimuth stand and 6-inch altitude and azimuth circles and two eyepieces.
„ 87. $3\frac{1}{4}$-inch Gregorian reflecting telescope with wooden tripod stand.
„ 88. Pendulum, with 5-foot brass suspension rod, working on knife-edges, by Thomas Jones.
„ 89. A Rhabdological Abacus. A contrivance invented by Mr. H. Goodwyn, consisting of a box filled with compartments, in which are square rods covered with numbers, which can be arranged so as to facilitate the labour of multiplying high numbers.
„ 90. An Arabic celestial globe of bronze, $5\frac{3}{4}$ inches in diameter.
„ 91. Astronomical time watch-case, by Professor Chevalier.
„ 92. 2-foot protractor, with two movable arms, and vernier.
„ 93. Beam compass, in box.
„ 94. 2-foot navigation scale.
„ 95. Stand for testing measures of length.
„ 96. Artificial planet and star, for testing the measurement of a fixed distance at different position-angles.
„ 97. 12-cell Leclanché battery.
„ 98. 2-foot 6-inch navy telescope, with object-glass $2\frac{1}{2}$ inches, by Cooke, with portable wooden tripod stand.
„ 99. 12-inch transit instrument, by Fayrer and Son, with level and portable stand.
„ 100. 9-inch transit instrument, with level and iron stand.
„ 101. Small equatorial sight instrument, by G. Adams, London.
„ 102. Sun-dial, by Troughton.
„ 103. Sun-dial, by Casella.
„ 104. Sun-dial.
„ 105. Box sextant, by Troughton and Simms.
„ 106. Prismatic compass, by Schmalcalder, London.
„ 107. Compass, by C. Earle, Melbourne.
„ 108. Prismatic compass, by Negretti and Zambra.
„ 109. Dipleidoscope, by E. Dent.
„ 110. Abney level, by Elliott.
„ 111. Pocket spectroscope, by Browning.
„ 112. Universal sun-dial.
„ 113. Double sextant, by Jones.
„ 114. Two models, illustrating the effects of circular motions.
„ 115. A cometarium.
„ 117. } Two old sun-dials.
„ 118. }

No. 119. Specimens of diffraction gratings, by Prof. W. A. Rogers.
„ 120. A 6-prism spectroscope, by Browning.
„ 121. Spitta's improved maximum and minimum thermometer.
„ 122. A 6-inch speculum, with flat; the speculum said to be by Sir W. Herschel, and re-figured by Sir J. Herschel.
„ 123. A 6-inch refracting telescope, by Grubb, with 3 eyepieces.
„ 124. Position micrometer, by Cooke.
„ 125. A 6-inch refracting telescope, by Simms, with eyepieces and solar diagonal.
„ 126. $3\frac{1}{2}$-inch portable refracting telescope, by Tulley, with tripod stand.
„ 127. Globe representing the visible surface of the Moon, by John Russell, R.A. (1797).
„ 128. Bichromate battery and Ruhmkorff coil.
„ 129. Slater's improved armillary sphere.
„ 130. 10-inch brass pillar sextant with counterpoise stand, by Troughton.
„ 131. Double box sextant, by Cary.
„ 132. Equatorially mounted camera with $2\frac{1}{2}$-inch portrait lens and telephotographic enlarging lens by Dallmeyer; iron pillar. [Presented by the executors of the late Sidney Waters.]
„ 133. $3\frac{1}{4}$-inch equatorial by Ross, with tall tripod stand, equatorial mounting, eyepieces, and micrometer. [Presented by Mrs. Mann.]

Besides the above, there is the following apparatus available for eclipse work :—

4 Slits for spectroscope.
2 Abney lenses used in photographing the corona.
2 Dallmeyer negative enlarging lenses.
1 Cœlostat with 16-inch plane mirror.

The following instruments are lent, during the pleasure of the Council, to the undermentioned persons :—

No. 4. The *Beaufoy* transit instrument, to the Observatory, Kingston, Canada.
„ 16. The *Wollaston* telescope, to Mr. R. Inwards.
„ 22. The *Matthew* equatorial, to Mr. J. Brett.
„ 23. The *Matthew* transit, to Captain W. Noble.
„ 27. (1) 30-inch transit and stand, to Mr. B. T. Moore.
„ 28. (2) 6-inch theodolite and stand, to Dr. A. A. Common.
„ 29. (3) Equatorial mounting, clock, &c., to the Rev. C. D. P. Davies.
„ „ Wire micrometer (No. 2), to the Rev. C. D. P. Davies.

No. 31. (5) $2\frac{3}{4}$-inch telescope and stand, to Mr. F. J. Wardale.
„ 42. (16) Artificial horizon, roof, and mercury bottle, to Mr. F. Robbins.
„ 47. (21) Box sextant and horizon, to Mr. C. H. Johns.
„ 50. (24) Prismatic compass, to Mr. Maxwell Hall.
„ 57. (31) Box sextant, to Dr. A. A. Common.
„ 69. (43) Telescope with rock-crystal object glass, to Sir W. Huggins.
„ 72. (*c*) Polarimeter, to Professor C. Michie Smith.
„ 76. (*b*) 5-prism direct-vision hand spectroscope, to Mr. E. W. Ellerbeck.
„ 85. Double-image micrometer, to Mr. B. T. Moore.
„ 119. Diffraction gratings, to Mr. B. T. Moore.
„ 123. 6-inch telescope, by Grubb (object-glass only) to Mr. W. E. Wilson.
„ 124. Position micrometer, by Cooke, to Mr. T. K. Mellor.
„ 125. 6-inch refractor by Simms, to Dr. A. A. Common.
„ 126. $3\frac{1}{2}$-inch portable refractor, by Tulley, to Mr. H. Sadler.
„ 128. Bichromate battery, to the Rev. W. J. B. Roome.
„ 131. Double sextant, by Cary, to Mr. F. Robbins.

The Gold Medal.

The Council have awarded the Society's Gold Medal to Mr. W. F. Denning, for his meteoric observations, his cometary discoveries, and other astronomical work. The President will lay before the Society the grounds upon which the award has been founded.

The Library.

A supplementary catalogue, containing the additions to the library from 1884 June to 1897 June, is in preparation and will shortly be published.

Obituary.

The Council regret that they have to announce the loss by death of the following Fellows and Associates during the past year :—

Fellows :—Antoine d'Abbadie.
J. W. Aldridge.
J. T. Barber.
Adolphe de Boë.
Frederick Brodie.
L. P. Casella.
H. B. Chamberlin.
J. J. Cole.
Samuel Cottam.
Rev. J. E. Cross.
T. G. E. Elger.*
Rev. Alexander Freeman.
William Godward.
Adam Hilger.
Rev. T. Mackereth.*
Joseph Maguire.
Albert Marth.
J. C. Robertson.
William Roxburgh.
Commander J. M. Share.
Charles Stewart.
E. J. Stone.
W. R. Vines.
C. C. Walker.

Associates :—Wilhelm Döllen.
F. A. T. Winnecke.

Antoine Thompson d'Abbadie was born in Dublin, of French parents, in the year 1810. His family returned to France in 1818, where he was educated. He early devoted himself to the study of geography, geodesy, and terrestrial magnetism. In 1836 August he determined the magnetic inclination at Paris. In 1837 he went to Olinda, in Brazil, where he studied the diurnal variations of the needle between the magnetic and terrestrial equators. The details of these observations were not

* Obituaries published 1897 Annual Report.

published till 1873, when they appeared in a memoir, entitled "Observations relatives à la Physique du Globe faites au Brésil et en Ethiopie." From 1837 to 1839 he was engaged with his brother, Michel Arnauld d'Abbadie, in making his first exploration of Ethiopia, and a second voyage was undertaken in the period 1839 to 1849. It is certain, however, that for some time in 1839 he was in Paris, as he there made a second determination of the magnetic inclination, to compare with that made three years previously. The results of these twelve years' geographical and geodetical work were published in 1873, under the title "Géodésie d'Ethiopie, ou Triangulation d'une Partie de la Haute-Ethiopie, exécutée selon des Méthodes Nouvelles."

What characterised the work of d'Abbadie was his method of observation. He had recognised how little precision attached to independent determinations of geographical positions—that is to say, those which are determined directly from observations of stars by field instruments, of which the best are exact only to about one or two kilometres. He conceived the plan, entitled "Géodesie Expeditive," of forming a network of triangles, more or less well proportioned, which included all the natural signal points that could be seen from the improvised stations on the heights where the party halted. This method gives a precision ten times greater than that of independent positions, and affords a valuable means of verification. Thus a connected chain of triangles was formed from the shores of the Red Sea to the confines of the country of Kaffa. This network included 8° 32′ in latitude and 3° in longitude, and furnished the positions of 857 points, confirmed also by the absolute determinations of a great number of latitudes, of longitudes from occultations, and of altitudes barometrically or hypsometrically determined. These observations were for the most part made with a small theodolite, which he had improved by placing the telescope parallel to the horizontal limb. This telescope, turning about an axis, can be pointed, by means of a prism before the object-glass, upon every object in azimuth or altitude. To this new form of geodetic instrument he gave the name of "Aba."

In the year 1851 d'Abbadie went to Frederiksvaern, in Norway, to observe the solar eclipse of that year, when he made some polariscopic observations of the prominences and corona, employing a 3·9-inch telescope, and power of 52, with a quartz plate and double-image prism. In 1860 he went to Spain, and observed the solar eclipse at Briviesca, again making polariscopic observations. In 1867 he observed at Algiers the annular eclipse of March 6. In 1882 he was the chief of the expedition sent out by the Académie des Sciences to Haiti to observe the Transit of *Venus*. In 1874 d'Abbadie sent a communication to the *Monthly Notices*, calling attention to an error he had discovered in the Radcliffe Catalogue. He erected an observatory at his Château d'Abbadia (Basses-Pyrénées), where he devoted himself to investigating the periodic variations of the deviation of the vertical.

The Geodesy of Ethiopia was the greatest work of D'Abbadie's life, and was a contribution to geographical science of the highest value. For though his results were some time ago seriously questioned, more recent researches have triumphantly established his triangulation, and proved the trustworthy character of the work done by him in this remote region. But D'Abbadie was also illustrious by reason of his varied researches, contained in numerous memoirs and notes communicated to the "Académie des Sciences," the "Société de Géographie," and to many other scientific societies, on astronomy, geodesy, physics, meteorology, geography, ethnography, and philology. The citation of the following titles will indicate the nature of some of his more important researches: "Études grammaticales sur la Langue Euskarienne" (1836); "Sur la Langue Kamtiga" (1841); "Sur la Langue Saho" (1843); "Découverte de la Source du Gibé ou Uma" (1847); "Résumé des Voyages faits par MM. Antoine et Arnauld d'Abbadie" (1849); "Note sur le Haut Fleuve Blanc" (1849); "Documents sur la Géographie du Bassin du Nil" (1852); "Sur les Tremblements de Terre et les Mouvements du Sol" (1852); "Mémoire sur le Tonnerre en Éthiopie" (1858); "Résumé Géodesique des Positions déterminées en Éthiopie" (1859); "Catalogue raisonné de MSS. Éthiopiens, comprenant 234 MSS." (1859); "Description d'un Instrument pour la Pratique de la Géodesie Expéditive" (1863); "Sur une Nouvelle Lunette Zénithale" (1865); "Études sur la Verticale" (1872); "Recherches sur la Verticale" (1882); "Les Fluctuations des Latitudes Terrestres" (1892); "Géographie de l'Éthiopie" (1883), &c. &c.

M. d'Abbadie belonged to the Institut de France for forty years, and for nearly twenty years he had been a member of the Bureau des Longitudes. Simple in his manner and kind-hearted in his nature, he was ever ready to give assistance to those who appealed to him for advice, and his loss is deeply regretted by all who were favoured with his acquaintance. He died in Paris 1897 March 19, at the age of eighty-seven years, signalising his love for Astronomy by bequeathing an estate in the Pyrenees, yielding 40,000 francs a year, to the Académie des Sciences, on condition of its publishing, within fifty years, a General Catalogue of Stars.

He was elected a Fellow of the Society on 1895 November 8.

John William Aldridge was born in London on 1824 August 24. His interest in astronomy was first roused by observing Halley's Comet at its return in 1835, but he never undertook any practical work in the science. He had no occupation, and devoted himself to extensive reading, not only in astronomy but also in law and medicine, and he was interested in cuneiform inscriptions. He was a regular attendant at the meetings of the Society when his health permitted. He died on 1897 December 11.

He was elected a Fellow of the Society 1890 May 9.

John Thomas Barber was born at Derby, 1825 July 23, and died at Norwood 1897 March 25. In 1854 he married Jane, eldest daughter of the late Rev. Matthew With. From 1864 till 1883 he lived at Spondon, in Derbyshire, and from 1883 till his death at Hoperay, Aston-on-Clun, Salop. He was of independent means. Mr. Barber took a keen amateur's interest in astronomy from the time when he was an undergraduate at Cambridge. In 1847 he published, together with Mr. J. Morgan, an illustrated account of the Great Aurora on October 24, as seen from the Cambridge Observatory, together with the auroras of 1846 September and 1847 March, and he calculated ephemerides for the return of comets. He set up at Spondon an 8-inch equatorial by Cooke, of York, and made observations with it of a miscellaneous kind ; but the telescope was not re-erected in the unfavourable situation of Aston-on-Clun. He was elected a Fellow of the Society on 1849 December 14.

Gustave Adolphe de Boë was born at Tamise in 1821. His childhood was spent at Douai, with his uncle, and he was educated, first at Lille and then at Brussels. His family lived at Antwerp, whither he returned in 1841, after a year spent in London in acquiring a thorough knowledge of English. It was not until 1858 that his interest in astronomy was awakened by reading Arago's *Astronomie Populaire*, then in course of publication. He was fascinated by what he read, and founded a private observatory at Antwerp (the first of its kind in Belgium), where he made numerous observations, both astronomical and meteorological. Among them may be mentioned the accurate determination of the latitude and longitude of his observatory, and his observations of the Transit of *Mercury* in 1878 and of the Transit of *Venus* in 1882. He was fertile in suggesting ingenious devices : the use of a daguerrotype plate in the mercury-trough ; a simple equatorial mounting; a method of measuring the magnifying power of a telescope, &c., &c. ; and, finally, perhaps his best work as an astronomer consisted in the interest which his own enthusiasm for the science awakened in others. His observatory (furnished with a 6-inch equatorial by Secretan, a small transit circle, a comet seeker, clocks, &c.) and his well-equipped library were always open to those interested in astronomy ; and he did much by writing in magazines and the daily papers to disseminate a knowledge of the chief facts and most important events.

He was elected a Fellow of the Society on 1881 January 14.

Frederick Brodie was born at Eastbourne, Sussex, on 1823 July 19, and was the youngest son of the Rev. Alexander Brodie, D.D., then Vicar of Eastbourne, a cadet of the ancient Scotch family of Brodie of Brodie, in the county of Nairn. His mother was Anna, daughter of John Walter, M.P., the founder of the *Times*. Mr. Brodie was educated at a private school at

Eastbourne and at the University of Edinburgh. His inclinations leading him in the direction of civil engineering, he was articled to Mr. J. M. Rendel, and in that capacity took part in the construction of the Chester and Birkenhead Railway. His connection with that undertaking led to his being appointed to a post in India in the early days of the Indian railways (1848), but when everything was settled, and his foreign service kit prepared, the promoters of the railway decided to cut down their expenditure, and Mr. Brodie refused to take up his appointment at a reduced salary. He remained therefore in England, and became Resident Engineer at the Esher Paper Mills, and continued there till he retired from his profession on his marriage, in 1853, with Elizabeth Anne, daughter of Mr. Thomas Fussell, of Wadbury House, Frome, Somersetshire, then the proprietor of the Mells Iron Works. Mr. Brodie erected in the grounds at Wadbury an observatory, proposing to carry on general astronomical work. The death of his wife in the spring of 1854 led him to quit Somersetshire, and the observatory was removed to an excellent site in a field belonging to his mother at Eastbourne, where he resided until after his second marriage, in 1858, to Ada Blanche, third daughter of the late Sir Robert W. Carden, Bart., M.P. He moved to Uckfield, in Sussex, in 1859, where for eighteen years he carried on observations of various kinds. The climate of Uckfield proving unsuited to his wife, who was never well there, Mr. Brodie sold his Uckfield property and bought a larger and better situated house, known as Fernhill, near Wootton, in the Isle of Wight, four miles west of Ryde. He died there on 1896 August 14, leaving, by his second wife, three sons and one daughter, two other children having died young.

Mr. Brodie's first observatory is described in vol. xvi. of the *Monthly Notices*, and was a remarkably successful structure as regards cheapness, lightness, and portability. It was made entirely of deal boards, and in planning it Mr. Brodie's engineering skill and experience stood him in good stead. A specification and plans, as modified by Mr. Brodie himself for the purpose, are given in the third volume of Chambers's *Handbook of Descriptive Astronomy*. The telescope with which Mr. Brodie started his astronomical work was an excellent $6\frac{1}{3}$-inch refractor. The object-glass was by Merz, of Munich, but the tube and mounting were made in England under Mr. Brodie's own superintendence. This telescope was afterwards sold to Sir William Keith Murray, of Ochtertyre, N.B., and was replaced by an American object-glass by Alvan Clark, of Boston, U.S., of $7\frac{1}{2}$ inches aperture, which had belonged to Mr. Dawes. On Mr. Brodie settling at Uckfield he sold his observatory and equatorial stand to Mr. C. L. Prince, by whom it was re-erected at Uckfield, the American object-glass being mounted in a new tube and on a new stand supplied by Mr. T. Cooke, of York. When Mr. Brodie broke up his establishment at Uckfield, in 1877, he remained houseless for about a couple of years, in which interval he went out to the

Cape of Good Hope, with some idea of remaining there for a time and carrying out astronomical observations there, but he was disappointed with the climate, and did not stay long in the colony, and eventually settled in the Isle of Wight, as stated above.

Mr. Brodie was a painstaking and accurate astronomical observer, and though his published contributions to our science were few and far between, he left behind him a large mass of memoranda (especially on Sun-spots and star clusters), selections from which might well be given to the world. Born and brought up a member of the Church of England, he quitted the Church in middle life and took up the tenets of the Plymouth Brethren, more or less, and turned his attention to the composition and publication of religious books, becoming himself a lay preacher. This eventually led to his abandoning, practically, all astronomical work, but his telescope was often used by his eldest son, Dr. C. G. Brodie, during his father's lifetime, and will probably be much more used in the future. Finally, it may be stated that Mr. Brodie was a very capable amateur carpenter, turner, and pyrotechnist, and, besides all that, was a great printer, having set up a large and well-equipped printing-office in each of his successive residences. He was elected a Fellow of the Society on 1855 February 9. G. F. C.

Louis Pascal Casella was born in Edinburgh in the year 1809. His father was a member of an old Italian family, and his mother was the daughter of General Ramsey, of Edinburgh. He was educated at Edinburgh, and at the age of twenty-seven he joined his father-in-law, the late Mr. Tagliabue, as an instrument maker, and eventually succeeded to that business. In the construction of meteorological, surveying, and engineering instruments, Mr. Casella attained a very high excellence, due to his innate intellectual skill and ability, and many important improvements and inventions in scientific instruments were made by him. Two inventions may be mentioned as being always associated with his name : the clinical thermometer, based upon Professor Phillips' maximum thermometer, which was brought into general use by the joint labours of Sir W. Aitken and Mr. Casella ; and the adaptation of the pressure gauge to the verification of thermometers for determining the temperature at great depths in the ocean where the pressure per square inch of surface can only be adequately expressed in tons. Mr. Casella did not do much work as an astronomer, but the indirect assistance he gave to astronomy by the excellent meteorological instruments he made has closely associated his name with many observatories. Mr. Casella's benevolence and kindly disposition were well known, and attracted to him wide respect. He died on 1897 April 23, at his residence at Highgate, at the advanced age of eighty-nine years. He was elected a Fellow of the Society 1860 June 8.

Humphrey Barker Chamberlin was born at Manchester in 1847, and died on 1897 May 16, at Egham, Surrey. At the age of seven he was taken to America by his parents, and served in the Military Telegraph Service Corps during the Civil War. He subsequently entered the drug business, combining a sound knowledge of chemistry with much commercial aptitude. In 1879 he suffered greatly from nervous trouble, which affected his eyes and made reading almost impossible. During the enforced leisure caused by this breakdown he made a small telescope, and started the interest in astronomy that continued until his death. In 1888 he determined to present a telescope to the University of Denver. With characteristic large-heartedness, he wrote to Dr. Howe, asking him to say, perfectly frankly, what telescope he would like, regardless of pecuniary limitations. Dr. Howe selected an aperture of 20 inches, and Mr. Chamberlin's reply was that "the question of a 20-inch telescope has been referred to the committee of ways and means, and I look for a favourable response." He was his own committee, and the response *was* favourable. He shortly after presented the University of Denver with two buildings, one for the main instrument and the library, the other for purposes of instruction—the students' observatory. The University set aside a plot of 14 acres in the outskirts of Denver, 4500 feet above the sea, for the site of the observatory, and the great telescope was installed in the summer of 1894. The 20-inch object-glass is by Clarke, and the mounting by Saegmuller.

Mr. Chamberlin was also greatly interested in mineralogy and microscopy. He founded a Microscopical Society in Denver, to which he presented a technical library. Not the least important work that he did for science was that of paying the expenses of a sound scientific training, in an unobtrusive way, for many young men with whom he came in contact.

Since 1890 Mr. Chamberlin resided chiefly in London. While here he founded the American Society in London, a task which his social qualities enabled him to accomplish with much success. He travelled extensively, and always made a point of seeing as many important observatories at home and abroad as he could.

He was married in 1871, and his widow and three children survive him. He was elected a Fellow of the Society on 1892 May 13. W. S.

John Jenkins Cole was born on 1815 March 25, at Plymouth. His father, Robert Cole, was a solicitor, who afterwards practised in London, and was well known as an antiquary. He was trained as a solicitor, but became an architect, and among the buildings designed by him in the course of a long working life may be specially mentioned the church of St. Mary, Abberley; Sir E. Antrobus's house at 146 Piccadilly; the offices of the Gresham Life Assurance Society opposite the Mansion House, and several

buildings in Throgmorton Street. He was architect to the Stock Exchange for 35 years, and designed the new Dome (forming a large extension of the "House" or market), the new offices in Throgmorton Street, and the long frontage in Old Broad Street, erected in 1882–88, besides carrying out numerous alterations and additions before and after those dates. He never undertook any astronomical work, though he was fond of looking through his own telescope, and he "had the pleasure (at Sutton, Surrey) of a clear observation of the Transit of *Mercury* in 1878," but he followed the work of others with keen interest, and was much attached to our Society, which he joined in 1862 March. About a fortnight before his death, and in anticipation of it, he desired his wife to write to the Secretary of the Society indicating some of the facts here mentioned, and specially recording that his greatest comfort was that he had been one of the fathers of sanitary science, and the means of abolishing the terrible system of *one* water cistern for all purposes the civilised world over. With the letter was enclosed a reprint of a letter in the *Times*, dated 1856 August 4, calling attention to this system, and its great dangers during the cholera epidemic of that time, suggesting the immediate erection of stand-pipes for drinking purposes and the ultimate abolition of the single-cistern system. The stand-pipes were set up forthwith, and Mr. Cole lived to see his principles universally adopted. While a member of the Society he resided successively at 24 Essex Street, Strand, at Hornsey Rise, and at Mayland, Sutton, Surrey, where he had a large room built for his telescopes. He died in this house on 1897 May 10, aged 82. He was twice married, and his wife, three sons, and a daughter survive him. He was elected a Fellow of the Society 1862 March 14.

Samuel Cottam was born 1828 December 3 in Manchester, where the Cottams have held a prominent position for more than a century. [The family claims descent, according to a tradition, from Kotta the Dane.] He was a chartered accountant, head of the firm of Messrs. S. E. Cottam and Son; a man of marked business capacity, and an excellent financier. He did not live to retire, for, though an invalid, he carried on work at his residence, Wightwick House, Higher Broughton, where he died 1896 September 1. He married, in 1858, Mary, youngest child of John Justin Southam, and two children survive—a son in orders, and a daughter who is an artist. Mr. Cottam was a man of varied attainments—a water-colour painter and a musician, a keen gardener and photographer, and a traveller in days when travelling was not so easy as now.

He was elected a Fellow of the Society on 1871 January 13.

The Rev. John Edward Cross was born at Red Scar, Preston, Lancashire, 1821 April 10, the son of William Cross. He was educated at Rugby and Christ Church, Oxford, and ordained in

1846 to a curacy in Bolton, where he remained till 1849, when he became curate and then vicar of Appleby, in Lincolnshire. He married, in 1854, Elizabeth, daughter of Admiral Sir Phipps Hornby, Rear Admiral of England. He became Prebendary of Leicester St. Margaret's in 1880, and in 1882 Rural Dean of Manlake. He resigned the living of Appleby in 1891, and went to live at Halecote, near Grange, Westmoreland. His health failed soon after, and he died, after a long and painful illness, at Scarborough, 1897 February 28.

Canon Cross was interested in astronomy from boyhood. One of his earliest recollections at Rugby was that of an eclipse of the Sun, on Sunday afternoon 1836 May 15, when Dr. Arnold altered the hour of divine service so as to allow the boys to watch the phenomenon. During his curacy in Bolton he made good use of a small telescope which ultimately became the finder to a larger equatorial. At Appleby he built a good observatory; and the mirrors for his large reflector were polished by his brother William.

[This brother, Colonel William Assheton Cross, who died in 1883, was also a Fellow of our Society. From the notice in the Council Report for 1884 February it is clear that the two brothers had much in common. Colonel Cross was educated at Rugby and Trinity, Cambridge; and in his college days had mounted a 5-inch by Dollond, once the property of the Rev. W. R. Dawes. From Lassell he learnt to grind mirrors, and made a 15-inch of great excellence, which he mounted equatorially. The following sentence is interesting from several points of view: "By a rude stroke of fate, one which denotes the rapid strides that have been made in the size of astronomical instruments in the course of one generation, Dawes's refractor, mentioned above, was degraded to become the finder of the new reflector." It may here be mentioned that the only surviving brother is the Right Hon. Viscount Cross, Lord Privy Seal.]

Canon Cross was, however, more interested in transit observations than in using his reflector. In his summer holidays, which were always spent in Rannoch, he took great interest in collecting all the details, and, as far as possible, discovering the stations used in the last century by Maskelyne in the Schehallien experiment; and though he never identified the actual spot where the principal observations were taken, he got a good approximation to it.

He was elected a Fellow of the Society on 1862 May 9.

Alexander Freeman was born in London 1839 January 28. He was educated at Merchant Taylors' School, and at St. John's College, Cambridge, where he graduated in 1861 as fifth wrangler. He was elected a Fellow of his college in 1862 May, and in the same year he obtained the Chancellor's medal for legal studies. Soon after this he took holy orders, and became M.A. in 1864.

Soon after taking his degree Mr. Freeman devoted himself to astronomy, which was the great love of his life. His first pub-

lished communication was to the *Messenger of Mathematics* in 1863, "on the variations of the node and inclination of a disturbed planet deduced from the lunar equation of latitude." Some further papers were published in the same periodical, in the *Proceedings* of the Cambridge Philosophical Society, and in volumes of the *Monthly Notices* from 1872 to 1892. These included observations of *Saturn's* ring, and occultations of stars by the Moon, and an interesting paper on a graphic conversion of stellar coordinates. In 1878 he published with notes a translation of Fourier's "Analytical Theory of Heat," which was produced by the Cambridge University Press. He also edited the third edition of Cheyne's *Planetary Theory.*

From 1880 to 1882, during the illness of the late Professor Challis, Mr. Freeman was appointed as his deputy, and he lectured for him on "Practical Astronomy and the use of Astronomical Instruments." On two occasions Mr. Freeman examined for the Smith's prize.

In 1882 Mr. Freeman married the daughter of Colonel Paterson, of the Buffs, and soon after that he was appointed Rector of Murston, near Sittingbourne, in Kent, which position he held until his death. Here he was greatly respected, and his kind, courteous and amiable manner made him a great favourite in the neighbourhood. He had always hoped to obtain an astronomical appointment, which would have been so congenial to his tastes, but in this he was unsuccessful.

He was a great reader and a hard-working man, and was always engaged in some astronomical work. He possessed an observatory with a $6\frac{1}{2}$-inch refractor, by Grubb, with which he spent the happiest hours of his life. About three years ago Mr. Freeman fainted while on a visit to the Archbishop of Canterbury, at Addington, and was compelled to take a three months' rest. He still, however, insisted on working hard, with the result that in 1897 March he had another prostration, from which he never recovered, and was confined to his room till June, when he died. This long and painful illness was borne most uncomplainingly, and throughout it he did all he could for his parish and for the large school of 400 children attached to his church. Mr. Freeman has left a widow and four children—three daughters and a boy.

He was elected a Fellow of the Society 1864 January 8.

William Godward was born in 1829 at Wakefield, where his father was a schoolmaster. At the age of eighteen he entered the *Nautical Almanac* Office, where his father and his uncle (William and John Godward) were at that time also serving, under Lieutenant Stratford; and he remained there for the long period of forty-three years, being appointed to the Chief Assistantship in 1869 on the retirement of Mr. Richard Farley. Among several improvements contributed by him to the *Nautical Almanac* may be specially mentioned his interpolation tables, which superseded others of a much more laborious character, and

are still in use ; as are also his improved elements of *Ceres*, given in the only paper he ever contributed to this Society (*Monthly Notices*, vol. xxxviii. p. 119). In 1866 he published his "Auxiliary Tables for Computing an Approximate Ephemeris of a Minor Planet." He retired from office on account of the age-limit in 1890, and died on 1897 May 19.

He was elected a Fellow of the Society on 1872 January 12.

Adam Hilger was born in Darmstadt in 1839, and in his early youth he showed a marked inclination for the mechanical work in which his father was then engaged. For some years he worked as a mechanical engineer in the Mint at Darmstadt, and afterwards entered Ertel's famous establishment at Munich. He next came to London, but soon left for Paris, where he had the good fortune to find employment with the firm of opticians, Lerebours & Secretan. During this engagement he constructed many instruments under the direct supervision of Foucault, and became acquainted with the theory as well as the practice of his art. After the war of 1870 he came to London, and became foreman with Mr. John Browning. Having completed a five years' contract he began business on his own account in Stanhope Street.

In the early memoirs of the pioneers in celestial spectroscopy both at home and abroad, references to Hilger's name are frequently to be found. He supplied many of the instruments with which the researches were carried out, thus gaining reputation and experience which he never ceased to increase. At the time of his death he was engaged upon work for all parts of the world, and his loss will be widely felt. He was always ready to undertake new work in which special difficulties had to be met, and he brought to it not only a wide practical experience but also an eager and active habit of mind. He paid special attention to the cutting and working of quartz and Iceland spar prisms, and had lately made very successful achromatic combinations of lenses, in which only natural crystals were used, and which were specially suitable for work with ultra-violet light.

Amongst many other matters which had engaged his time and thoughts, we may refer to one in particular in the hope that it may receive further attention and be brought to perfection—viz. a form of governor for controlling clockwork in cases where there are considerable variations in the power or the load.

Mr. Hilger died on 1897 April 23, at Brighton, from the effects of a bicycle accident.

He was elected a Fellow of the Society on 1892 February 10.

Joseph Maguire was born at Corstoon, Drumconrath, co. Meath, in or about the year 1800. [The register of his birth cannot be found. He himself believed that he was a centenarian, but evidence, collected after his death, points to the conclusion that his age was ninety-six.] He died on 1896 April 8 at his

residence, 12 Grove Road, Lakenham, Norwich, and was buried with Roman Catholic rites.

He was an able land surveyor, and after being engaged for many years in surveys in the North of England, became managing clerk to Messrs. Wright and Woodrow, the principal land agents in Norwich. He married, in 1864, Miss Harriet Agnes Pettit, daughter of an organist and composer in Norwich. His wife predeceased him, and there was no family. He retired from business some twenty years ago, but continued to live in the same residence till his death.

He contributed several papers to the *Monthly Notices* on eclipses and occultations. His last two papers, published in 1885, give particulars of the thirteen total solar eclipses which have been visible in the British Isles between 878 and 1724, two excellent maps showing the lines of totality. The last sentence of one of these papers may perhaps be quoted :

"It appears from the limiting lines of these eclipses that London has been twice totally eclipsed, Dublin twice, and Edinburgh five times ; and, assuming the calculations to be correct, the Moon's shadow would have fallen upon every spot of the British Isles except a small space at Dingle, on the west coast of Ireland."

The calculations were made some ten years before publication of the paper ; but even then the author was in the seventies. The tables used were generally Hansen's. Among the papers found at his death was a map of the British Isles showing the course of the 1927 eclipse, which suggests that he contemplated continuing this work, but was no doubt prevented by advancing age. He was elected a Fellow of the Society on 1865 February 10.

Albert Marth was born at Colberg, in Pomerania, on 1828 May 5, and was left an orphan at an early age. The desire of his mother had been that he should enter the Church, but after some time devoted to the study of Hebrew and theology, his early enthusiasm for mathematical science asserted itself, and he resolved to apply himself exclusively to astronomy, which he studied at the University of Berlin, subsequently going to Königsberg, where he became a pupil, and then an assistant of Dr. C. A. F. Peters, professor of astronomy at that university. A schoolfellow of his once said, "Marth may study what he likes, but he is and always will be an astronomer." This early prediction was amply fulfilled in after years, for throughout his life Marth devoted himself solely to that science ; indeed, among the numerous memoirs and papers he published, which evince his wide knowledge of general astronomy, we do not find one dealing with any other subject. It cannot be doubted, however, that the influence of a master of such consummate ability as Peters largely contributed to develop in Marth that accurate conception of astronomical problems which he in many ways so conspicuously displayed.

Marth's earlier contributions to astronomy were all published

in the *Astronomische Nachrichten*. In 1852 he published an ephemeris of Westphal's Comet from observations made at Königsberg, and in the following year he made some observations of *Hebe* with the meridian circle of that observatory. In 1853 he became an assistant to Mr. Hind, who was then astronomer at Mr. Bishop's observatory in the Regent's Park, and whilst in that position in 1854 March 1 he discovered the minor planet *Amphitrite* (29), anticipating by one day Pogson's independent discovery of the same planet. He remained at Mr. Bishop's observatory under two years, contributing in that time to the *Astronomische Nachrichten* the elements and ephemerides of the minor planets *Euterpe*, *Amphitrite*, *Massilia*, and *Urania*, besides the elements of Comet I. 1854. In 1855 he succeeded Rümker as astronomer at the Durham Observatory, where he remained till 1862. During this period he published in the *Astronomische Nachrichten* of 1856 August 26 the first part of his "Researches on Satellites." He proposed to investigate the motions of the satellites of *Saturn*, *Uranus*, and *Neptune*, and to elucidate their theories. In this memoir he confined himself to the preliminary mathematical investigations which are necessary, and incorporated new formulæ involved by the principle he adopted. Observations of *Saturn's* satellites had been made by Bessel in the case of *Titan* by measuring the positions with reference to the ring, and of *Iapetus* and *Rhea* by reference to *Titan*. Marth pointed out that such positions of *Titan* rest on the assumption, which is not beyond doubt, that the centre of the figure of the ring coincides with the centre of the planet, and that the investigation of the orbits of the two other satellites is only possible after the motions of *Titan* have been duly determined. He points out that for a series of observations of a satellite to be made a contribution of full value towards an investigation of its motions, it is essential to adopt such a method in observing that the results of reduction may give positions of the satellite referred to the centre of the planet. In the first part of the paper he deduces the formula by which the apparent positions of the satellites referred to the planet, either by means of angular distance and position angle, or by differences of right ascension and declination, may be calculated from given elements and given places of the planet, and by which likewise the equations of condition may be found which exist between variations of the positions and corresponding variations of the elements. He then shows how to determine the approximate elliptic elements of the orbits which are to be used in the calculations, and he lastly takes into account the disturbances introduced by the action of the Sun and other bodies. This important paper, which was noticed in the Council's report for 1857 February, formed the introduction to the numerous ephemerides of satellites which he computed annually from the year 1870 to the time of his death, nearly all of which were published in the *Monthly Notices*. No further communication on the theoretical question appeared until 1887, when he sent to the *Monthly*

Notices a paper, "On the Formulæ for Computing the Apparent Positions of a Satellite and for Correcting the Assumed Element of its Orbit." He continued his researches on satellites in several smaller communications which appeared from time to time in the *Monthly Notices*, and in which he constantly urged the importance of increased observations being secured to enable him to perfect his ephemerides.

During Marth's sojourn at Durham three further important papers were communicated to the *Ast. Nach.*; the first in 1856, "Ueber die Berechnung der Coordinaten in Ellipsen von starker Excentricität"; the second in 1860, "On the Polar Distances of the Greenwich Transit Circle," which was a lengthy and stringent criticism of the Greenwich methods and reductions; the third in 1862, "Vorschlag eines neuen Verfahrens die von der Biegung eines Instruments und von den Unregelmässigkeiten seiner Zapfen erzeugten astronomischen Beobachtungsfehler zu bestimmen." This was a proposal of a new method for determining the flexure and pivot errors which was specially applicable in the case of an instrument with a prism in the centre. These proposals formed the subject of a controversy between Marth and M. Loewy which appeared in the *Monthly Notices* in 1882.

In 1862 he left Durham to join Mr. Lassell as his assistant at Malta, where the 4-foot telescope was erected. With this instrument he discovered and formed a catalogue of the positions of 600 nebulæ. Many of these nebulæ were found independently by D'Arrest and Stephan, whose observations proved the remarkable degree of accuracy with which Marth had determined positions with so unwieldy an instrument. He quitted Malta sometime in 1865, and resided in London for a few years, till 1868, when he was appointed astronomer to Mr. Newall, at Gateshead, to assist in the construction and erection of the 25-inch refractor at that observatory. This position was occupied for a few years, when Marth settled again in London, which he finally quitted in 1883 on his appointment to Colonel Cooper's Observatory at Markree, a position that he retained for the remainder of his life. In 1882 he was sent out to Montagu Road, Cape of Good Hope, in charge of an expedition to observe the transit of *Venus* at that station. He was successful in his observations, which he considered fairly good, notwithstanding much atmospheric disturbance at the time.

Marth was a most active and accurate computer, and he well earned the gratitude of astronomers for the tables and ephemerides he regularly prepared for so many years for observations of the satellites, and for physical observations of *Mars*, *Jupiter*, and the Moon. It cannot be doubted that the assistance thus afforded to observers has been the means of considerably advancing knowledge. In the papers already cited, and in many others, Marth showed his capacity for dealing with questions of theoretical astronomy under new and original aspects. In this connection we may cite his papers "On the Computation of the Equation of the Centre in

Elliptical Orbits of Moderate Eccentricities," "On a Simple Solution of Kepler's Problem," and on "Two Auxiliary Tables for the Solution of Kepler's Problem." We may also mention the interesting paper he published in the *Monthly Notices* for 1885 March, entitled "Data for a Graphical Representation of the Solar System," the principle of which we may venture to quote. "The Sun's centre being the common focus of all the orbits, a plane passing through the Sun's centre perpendicular to the ecliptic will intersect all the orbits. Let this plane rotate, and let, for each orbit, the tracing be represented which the point of intersection produces on the plane in the course of a full rotation, and which for the present purpose may perhaps be called the 'ecliptical intersect' of the orbit. The form or shape of the tracing or intersect depends on the elements i, e, ω of the orbit: i, the inclination to the ecliptic; e, the eccentricity; and ω, the angular distance or departure of the perihelion from the ascending node ☊. A circular orbit in the plane of the ecliptic would accordingly be represented by a point or dash, a circular orbit inclined to the ecliptic by a circular arc, an eccentric orbit in which ω is $=\pm 90°$ by an arc of another curve. In order to lay down the 'ecliptical intersect' of any actual orbit, the coordinates of a sufficient number of points must be known, through which the curve may be easily drawn by hand. The coordinates required are the curtate distances from the Sun and the distances from the plane of the ecliptic, or $r \cos b$ and $r \sin b$, if r denotes the radius vector and b the latitude, to which must be added the corresponding ecliptical longitudes l and also the true anomalies v."

Marth was never married, and gave up all family life in order to pursue his scientific studies. His aspiration had been to be able to make observations with a perfect instrument in the best climate, but his ideal was never realised, and this disappointment to his sensitive nature, coupled with indifferent health, seems to have rendered his life not too happy. He had a wide and accurate knowledge of astronomical history and a remarkable memory. An old-standing complaint, brought about by his sedentary habits, assumed an acute form while on a visit to Heidelberg, and he quietly passed away on 1897 August 6.

The honorary degree of M.A. was conferred upon him by the University of Durham. He was first elected a Fellow of the Society on 1854 May 12 and resigned in 1857; subsequently he was elected again a Fellow on 1878 January 11. E. B. K.

William Roxburgh was the youngest son of the late Dr. William Roxburgh, sometime Superintendent of the Botanic Gardens, Calcutta, and author of the *Flora Indica*. He was born at Calcutta on 1812 May 15. He was educated at the New Academy, Edinburgh, and afterwards entered the University of that city, where he took the degree of M.D. in 1835. In the following year he settled in London, and pursued his medical

studies at the Middlesex Hospital. He was a member of the original Council of the Royal Botanic Society of London, and took an active part in planning the gardens and in promoting the interests of that Society. In 1846 he was elected a Member of the Royal Institution of Great Britain, and formed a close friendship with the late Professor Faraday. He was for some years Physician to the Western General Dispensary, and was in 1857 admitted a Fellow of the Royal College of Physicians, London.

In consequence of a severe illness he retired from the active practice of his profession, and removed to Edinburgh in 1859. After residing there and at several places in England, he came to Ipswich in 1886, where he died on 1897 April 7.

During the last twenty years of his life he took special interest in Solar Physics. He was elected a Fellow of the Society on 1853 June 10.

Charles Stewart was born at Bo'ness, Linlithgowshire, in 1818, and died at his residence, Ackender House, Alton, Hants, 1897 September 6. For many years Dr. Stewart had a private school, from which he retired in 1889. He was elected a Fellow of the Society 1865 November 10, and was specially interested in meteors and nebulæ.

Edward James Stone was born in London on 1831 February 28. He was the elder son of Mr. Edward Stone, a member of a Devonshire family, who carried on a successful business in London. Young Stone was educated privately, but, for the benefit of his health, a large portion of his early youth was spent among his relatives in the country. His preparatory education was therefore much interrupted, his parents preferring that he should enjoy for a time the freedom of a country life, in order that his strength might be sufficiently established to enable him eventually to assist his father in his business. During these early years, young Stone, who was extremely partial to his Devonshire home, showed no indications of the innate talent he undoubtedly possessed. On his return to London, however, as his age advanced, a love of private reading was noticed, though his opportunities were very limited, for he had passed his twentieth year before he was induced to begin the study of classics or mathematics. Soon after this he was persuaded by his friends to become a student at King's College, London, and he considered that this new departure was the turning-point in his life. He has often remarked that he owed his successful career at Cambridge to the careful training he received there, especially to the Rev. T. G. Hall, who was the first to discover his latent mathematical power, and to the Rev. Dr. Major, who assisted him privately with his classics, etc.

At King's College Stone soon gave evidence of the mathematical talent that up to this time had remained dormant. He was very enthusiastic, and his progress both in classics and

mathematics was rapid. In his twenty-fourth year he entered Queens' College, Cambridge, and in 1856 he gained a scholarship. His abilities were at once recognised, and it was soon predicted by his tutors that he would take a high place in the mathematical tripos. He was, however, handicapped by occasional attacks of nervous prostration, one of which was so serious that he was unable to attend the tripos examination in 1858, thus deferring his degree for a year. In 1859 January, he graduated B.A. as Fifth Wrangler, and shortly afterwards he was elected a Fellow of Queens' College. Considering the comparatively little educational training he had had in his youth ; that his higher education was not commenced until he had passed his twentieth year ; that he went up to Cambridge much later in life than most freshmen ; and that his health at college was never robust, his scholarship in 1856 and his high degree in mathematical honours in 1859, are somewhat remarkable examples of academic success.

It was the intention of Mr. Stone to remain at Cambridge as a resident Fellow of his college, devoting himself to the care of pupils ; but on the appointment, in 1860, of the Rev. Robert Main, Chief Assistant at the Royal Observatory, to the post of Radcliffe Observer at Oxford, some of his Cambridge friends, knowing that he had shown an interest in astronomical questions, recommended him to the Astronomer Royal as a suitable person to fill the vacancy at the Observatory. His official appointment as Chief Assistant was confirmed by warrant of the Board of Admiralty on 1860 October 1. Airy, in his next annual report to the Board of Visitors, wrote :—"I have every reason to believe that Mr. Stone will well support the scientific honour of the Observatory, and its reputation for order and accuracy in the conduct of business. As First Assistant, Mr. Stone is intrusted with the fullest confidence from me, and the fullest superintendence of the Observatory in general."

When Mr. Stone first entered upon his official duties at the Royal Observatory, he was not much acquainted with the ordinary practical work required at Greenwich, but, with the help of the senior astronomical assistants, it was not long before his own personal interest in the meridian and equatorial observations became apparent, but he was only occasionally called upon to observe with any of the instruments, or to assist in the ordinary reductions of the observations. He was thus enabled to master easily the general routine business, and to undertake several original investigations, usually based on the Greenwich published results. These were not strictly official, but sometimes the subject was a special suggestion of the Astronomer Royal.

During the ten years that Mr. Stone remained at Greenwich, one of the principal astronomical questions under discussion was the importance of obtaining a new determination of the value of the constant of the Sun's horizontal mean equatorial parallax. Both Hansen and Le Verrier had found that to reconcile the observed places of the Moon and planets with the corresponding

theoretical places, it was necessary to make a considerable increase in the mean adopted value, as determined by Encke from the observations of the transit of *Venus* in 1769. Airy, who always took much interest in this problem, gave, in 1857, an oral statement at the April meeting of the Society, suggesting a redetermination of the value of this constant indirectly from comparisons of *Mars* and neighbouring stars at the oppositions of 1860 and 1862, both being particularly favourable for the purpose. Consequently, several successful series of comparisons were obtained at the principal observatories in both hemispheres. At Airy's request, Mr. Stone undertook the discussion of the observations made at Greenwich, the Cape of Good Hope, and Williamstown, near Melbourne. He entered upon this investigation with great enthusiasm, having little or no desire for extraneous help, although Airy offered any computing assistance that he might require. The resulting value was 8″·94, differing very little from the values indicated by Hansen and Le Verrier from theory, and from Winnecke's result determined from a different combination of observations of *Mars* and stars. This agreement gave Mr. Stone at the time a great confidence in the accuracy of his own calculations, and he firmly believed that his new value must be very near the true one.

A more important memoir on the same subject—"A Rediscussion of the Observations of the Transit of *Venus*, 1769"—was communicated to the Society in the autumn of 1868, and published in the *Monthly Notices*, vol. xxviii. For this paper the Council in the following January awarded the Gold Medal to Mr. Stone. It occurred to him that a new discussion of the observations of this transit might lead him to the discovery of some sources of systematic error or wrong interpretation affecting Encke's value. He was intensely interested in his own interpretations of the various phenomena of apparent and real internal contact, as inferred from the notes of the different observers, and he implicitly believed that his interpretations were correct, and that they led to a solution giving a satisfactory indication of an interval of nineteen seconds of time between the internal contact and the breaking of the black drop. His conclusions, however, were not altogether free from criticism, though he had his usual confidence in the resulting value 8″·91. He considered that this value was entitled to great weight, and was in most satisfactory agreement with those that had lately been otherwise obtained—an opinion evidently shared by the President, Admiral R. H. Manners, who, on presenting the Gold Medal to Mr. Stone, remarked that "by this important investigation Mr. Stone has earned for himself the gratitude of astronomers of all countries. He has shown beyond all doubt that the method pursued by his illustrious countryman, Halley, when fairly treated, is capable of furnishing a value of the solar parallax commensurate in precision with the expectations formed of it. But this is not all. Mr Stone, by his researches in this instance, has wiped from astro-

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nomy a reproach, which did not, indeed, legitimately attach to it, but which only one of those intellectual triumphs which from time to time have adorned the annals of our science was capable of extirpating."

A reference to the *Monthly Notices* and *Memoirs* of the Society shows at once that Mr. Stone was indeed a hard worker all the time he was at Greenwich. Sometimes he had more than one investigation in hand at the same time, in addition to the daily official correspondence and other routine matters that usually devolved upon him. Some of these researches were of great importance, the results of considerable calculation, while most of the final preparation of his memoirs was performed in his leisure hours at home. His principal memoirs about this time—"On the Proper Motions of the Stars in the Greenwich Seven-Year Catalogue," "On the Sun's Mean Equatorial Horizontal Parallax from Observations of *Mars* and Stars," "On the Accuracy of the Fundamental Right Ascensions of the Greenwich Seven-Year Catalogue," "On the Constant of the Lunar Parallax," and "On the Constant of Nutation"—are all of some length, and printed in the *Memoirs*. His contributions to the *Monthly Notices* were very numerous during these ten years on almost every branch of current astronomy, including a valuable paper on "Bessel's Mean Refractions." In addition to all this work, Mr. Stone, as Honorary Secretary, took a very prominent part in the business of the Society from 1866 to 1870, and in the preparation of the annual reports of the Council for these years.

In the spring of 1870 Sir Thomas Maclear, Her Majesty's Astronomer at the Cape Observatory, resigned his office, leaving a large mass of valuable meridian observations unreduced. Mr. Stone, who was beginning to be anxious for a more independent position, became the successful candidate for the vacant post. He received official notice of his appointment early in June. He landed at Cape Town in the following October, and soon afterwards took up his residence at the Observatory. His promotion was considered a very appropriate one, though it was certainly a heavy task laid upon the new director to reduce the accumulated mass of arrears of his predecessor, and "to render these results available for the use of astronomers with as little delay as possible," as well as to continue the ordinary current work of the Observatory. Such were his official instructions on leaving England! How successfully he performed this task is now a matter of astronomical history.

The principal object Mr. Stone had in view on accepting the position of Her Majesty's Astronomer at the Cape was the formation of a standard catalogue of southern stars to about the seventh magnitude from observations made with the Cape transit-circle. He hoped to be able to publish a catalogue in which the star places would favourably compare in accuracy with those given in the Greenwich catalogues. He expected to take ten

years for the completion of this scheme. It should be remembered that Mr. Stone never had much clerical assistance during the whole time he was at the Cape, and therefore for all purposes he had to rely upon the ready co-operation of his few established assistants. Those who have had anything to do with the compilation of a standard star catalogue can understand that the preparation of the Cape Catalogue of more than 12,400 stars must have been an immense labour with so small a staff. Mr. Stone apparently worked continuously on it, occasionally assisted by Mrs. Stone, while he also took a share of the observations. He remarks in the preface to the Catalogue :—"Besides the general organisation and arrangement of the work, and the making in each year sufficient observations to check the instrumental adjustments, and the general working of the transit-circle, I have made it a rule to throw my personal weight upon any part of the work which, from time to time, appeared to flag. I have thus taken a direct share in the work to an extent which appears somewhat unusual on the part of the director of large observatories, but this was inevitable."

The reductions of this standard catalogue of 12,441 southern stars were completed, and a portion of the catalogue formed, before Mr. Stone left the Cape on 1879 May 13, but there was still a considerable amount of revision and examination requiring his attention. This, and the superintendence of the printing of the volume, occupied much of his time after his return to England. The catalogue was published in 1881, for which, in the same year, the French Académie des Sciences awarded him the Lalande astronomical prize. Soon after he commenced his residence at the Cape Observatory Mr. Stone, according to his official instructions, directed his thoughts towards completing the reductions of the meridian observations made under the direction of Sir Thomas Maclear during the years 1856 to 1860. The volume of results for 1856 was published in 1871, for 1857 and 1858 in 1872, and those for 1859 and 1860 in 1874. The general catalogue of 1159 stars derived from all these observations, reduced to the epoch 1860, was published in 1873. A second general catalogue of 2892 stars for the epoch 1840, based on Maclear's meridian observations made between 1834 and 1840, was published in 1878.

Mr. Stone was fortunate in being able to observe the total eclipse of the Sun on 1874 April 16. As the central line of shadow passed through a region not easily accessible to European astronomers, he, as their representative in South Africa, was very anxious that the eclipse should not pass away unrecorded. Accompanied by Mrs. Stone, who assisted him in the observations, he selected a station at Klipfontein, in Namaqualand. Although his instrumental equipment was limited to a 4-inch telescope, mounted as an altazimuth, and a small spectroscope, he succeeded in observing the reversal of the Fraunhofer lines at the disappearance of the Sun's limb, and in making many other important observations of the structure and composition of the

corona. The details of this expedition are given in vol. xlii. of the *Memoirs*. While in Namaqualand Mr. Stone also made a series of magnetical observations at four stations, the first made in that region of South Africa. He took no part in the many eclipse expeditions organised in England since his return from the Cape; but, at the invitation of Sir George Baden-Powell, he joined a private party on board the yacht *Otaria*, who were proceeding to Novaya Zemlya to witness the total eclipse of the Sun on 1896 August 9. The sky was fortunately clear during the totality, and Mr. Stone was one of the few astronomers who made any successful observations of this eclipse. The results were communicated to the Society in the following December, and will be published in the next volume of the *Memoirs*.

Although Mr. Stone's occupations at the Cape were absorbing, he yet found time to prepare several important memoirs, some on astronomical subjects, and others on some point in physical science. The volumes of the *Monthly Notices* give sufficient evidence of this. He also communicated to the Royal Society several papers, including results of experiments made at Greenwich on the heating power of stars; an experimental determination of the velocity of sound; magnetical observations made in Namaqualand; and on a cause for the appearance of bright lines in the spectra of irresolvable star clusters. The transit of *Venus* in 1874 was favourably observed at egress by Mr. Stone and his assistants at the Cape Observatory.

After the publication in 1877 of the official report on the observations of the transit of *Venus* in 1874, drawn up under the supervision of Sir George Airy, from which a mean solar parallax of $8''{\cdot}76$ was deduced, Mr. Stone made a rediscussion of the various observations of contact, in accordance with his own particular views on the subject. He obtained a mean parallax of $8''{\cdot}89$ from his interpretation of the contact observations, and he states that his result absolutely negatived any value smaller than $8''{\cdot}84$, or larger than $8''{\cdot}93$.

The Rev. R. Main, Radcliffe Observer, died in the spring of 1878, and towards the end of the year Mr. Stone was appointed by the Radcliffe Trustees to succeed him. He, however, was not able to take up his residence at Oxford before the end of 1879 June, but Professor Pritchard had the general charge of the Observatory in the meantime. Mr. Stone was very gratified at this appointment, especially as it enabled him to renew his association with former astronomical friends, and with the proceedings of the Society.

Mr. Stone was a member of the Transit of *Venus* Committee appointed by the Royal Society to advise upon the conduct of the observations to be made in the transit of 1882, and also of the Executive Committee, on which he acted as the directing astronomer of the arrangements. He was intrusted with the general superintendence of the preliminary training of the observers at the Radcliffe Observatory, and of the instrumental equipment of

the different stations. After the transit he undertook, with the assistance of a special computer, all the reductions, and also the discussion of all the observations of the various phases of external and internal contact. The interpretation of the true meaning of the notes of the observers entailed a considerable personal labour on Mr. Stone; but eventually he determined the value of mean solar parallax from this transit to be 8″·832. The final report of the Government Committee was drawn up by Mr. Stone, and published in 1887 by order of the House of Commons.

While at Oxford Mr. Stone usually controlled the daily work of the Observatory, devoting much personal attention to the supervision of the reductions, but he took no active share in the ordinary observations. In the autumn of 1888, however, he made a special series of heliometer observations of the minor planet *Iris* with comparison stars, in accordance with a scheme of combined operations proposed by Dr. Gill, for a new determination of the value of the constant of solar parallax. He entered upon this duty with great energy, although the watches were long and wearying, extending generally to about 2 A.M. He took much interest in these observations, hoping to make the series as complete as possible; but though he obtained several sets of comparisons, the Oxford variable climate prevented him from making it as perfect as he had wished. In the following year Mr. Stone also made several attempts to observe the minor planets *Victoria* and *Sappho*, for the same purpose; but owing to the faintness of the planets and broken weather, no satisfactory observations were made.

The Radcliffe Catalogue of 6424 stars for the epoch 1890, published in 1894, is a valuable work, and a most important contribution to sidereal astronomy. This catalogue contains the positions of all the stars to the seventh magnitude, from the equator to 115° N.P.D., excepting those in clusters, observed with the transit-circle during the years 1880 to 1893. The positions of some fainter stars to fill existing lacunæ, and of a few others observed beyond the adopted limits for some special purpose, are also included in the catalogue. This important work may be considered as the continuation and completion of the original plan of operations commenced at the Cape Observatory in 1870, and there can be no doubt that upon Mr. Stone's two noble standard star catalogues his reputation as a practical astronomer will principally rest.

The Royal Society "Catalogue of Scientific Papers" to 1883 contains the titles of ninety-two separate papers by Mr. Stone. About sixty more were communicated by him to the Royal Astronomical Society between 1884 and 1897. Many of these are of great interest, but the limited space at our disposal forbids any special reference to them here. The titles may be easily found in the various indexes to the *Monthly Notices*. The long series of controversial papers on a supposed change in the adopted length of the mean solar day ought not, however, to be passed over without some brief

notice, as this was a question that largely occupied his attention during the last fourteen years of his life. On 1883 May 11, he communicated to the Society a paper stating that he had discovered the principal cause of the large errors existing between the positions of the Moon deduced from Hansen's Lunar Tables and observation. He attributed these increasing tabular errors to a change in the unit of time, caused by the adoption in 1864 of Le Verrier's expression for the sidereal time at mean noon instead of that of Bessel, which had been previously in use in the calculations of the *Nautical Almanac*. Mr. Stone contended that in consequence of this change of formulæ in the *Nautical Almanac* calculations of the sidereal time at Greenwich mean noon, the unit of mean solar time was practically altered to such an extent that at the end of 1881 the difference amounted to nearly twenty-seven seconds, increasing at the rate of about $1^{s}\cdot46$ per annum. This explanation was given by Mr. Stone with much confidence in its accuracy, but Professors Adams and Cayley at once pointed out in the clearest and simplest manner that this view of Mr. Stone was erroneous, and that the true rate of increase per annum was only 1-365th part of that amount, or $0^{s}\cdot004$. However, notwithstanding the expressed opinions of these and several other leading mathematical astronomers, it is remarkable that he sincerely and firmly believed that his theory was correct, and that the substitution in 1864 of Le Verrier's Solar Tables for those of Carlini fully accounted for the increasing errors of Hansen's Lunar Tables, even after his attention had been specially drawn to the point where his reasoning was shown to fail. So strong was he in this belief, that he was never able to perceive, or to acknowledge in any way, that his arguments could possibly be unsound, though it had been practically proved by calculation that whether Le Verrier's or Carlini's Tables were used to compute the sidereal times at mean noon, the tabular errors of Hansen's Tables would be substantially the same. On the contrary, he continued year after year to carry on the controversy with excellent temper, defending his conclusions with great earnestness and pertinacity, due in some measure to his naturally sensitive disposition.

Mr. Stone was elected a Fellow of the Society on 1861 January 11. He at once took an active share in the discussions at the meetings. He was a member of the Council from 1863 to 1870, and again from 1880 to 1897 ; Honorary Secretary from 1866 to 1870 ; and President, 1882–84. During his Presidency he presented the Gold Medal of the Society to Dr. B. A. Gould in 1883, and to Dr. A. A. Common in 1884, after delivering an appropriate address on each occasion. He was elected a Fellow of the Royal Society in 1868, and he served two years on the Council, 1881–83. He was an Honorary Fellow of Queens' College, Cambridge ; M.A. (Cantab. et Oxon.) ; a Member of the Board of Visitors of the Royal Observatory, and of the Meteorological Council ; an Honorary Doctor of Natural Philosophy in the University of Padua ; a Corresponding Member of the Société

Nationale des Sciences Naturelles et Mathématiques at Cherbourg; and an Honorary Member of the Literary and Philosophical Society of Manchester.

From his youth Mr. Stone was very fond of fly-fishing and shooting. When resident at Greenwich and Oxford, he generally spent a portion of his holidays every year in these pursuits. He was accustomed to say that his fishing expeditions on the Irish and Scottish rivers were to him the most agreeable outdoor recreation, taking away all his thoughts from observatory work, and even from astronomy itself. Only a week before his death he was on a fly-fishing excursion in North Wales, and had had a slight accident by the upsetting of his boat. Hoping to avoid a chill, he rowed quickly back to the hotel, a distance of about two miles. In doing this he apparently overstrained his heart. About three days after his return to Oxford pneumonia set in, though he was able on the day preceding his death to spend some time in the Observatory, selecting a site for setting up some instruments for trial preliminary to his proposed journey to India to observe the total solar eclipse on 1898 January 22. On the same night he became much worse, but there was then no suspicion that he was in immediate danger. The end, however, came very suddenly, from cardiac failure, shortly before noon on Sunday, 1897 May 9, when he quietly passed away in the sixty-seventh year of his age.

By the almost sudden death of Mr. Stone, the Society has been deprived of one of the most devoted of its members. He was rarely absent from the Council table or at the ordinary meetings, where his well-known face will in future be sadly missed. It has been truly said that when joining in any discussion in which he felt a personal interest, "the brightness of his eyes, and the rapidity of his utterance, revealed the earnestness and energy of his spirit." Though he was ever ready to enter into an animated debate to defend his own conclusions, he was always genial, even when he differed strongly from others on some controversial point, while at the same time those who did not agree with his opinions usually respected the conviction with which he apparently held them. He has been known to spend hours writing and re-writing paragraphs stating his special views on astronomical questions, so as to avoid giving offence to anyone, though occasionally he felt that he must write plainly. The writer, looking back to his ten years of close official and private association with Mr. Stone at Greenwich, is able to recall to his mind many instances of this marked feature in the defence of his own opinions, and in his criticisms of another's work, as well as some most pleasing reminiscences of his assistance and kindness in many ways.

On 1866 September 12 Mr. Stone married a Devonshire lady, Grace, daughter of Mr. John Tuckett, by whom he leaves one son and three daughters.

E. D.

William Reynolds Vines was born in Bristol in 1817. He began life as a Moravian missionary, and served in Jamaica for some years, until he was invalided home. He eventually established a large and successful school at Elm Grove, Ealing, but was obliged to give it up in 1863 on account of ill-health. He had married in 1847, and had one son (now Sherardian Professor of Botany at Oxford). From 1863 onwards he travelled a great deal, but ultimately settled in 1889 at Auckland, New Zealand, where he died on 1897 November 16. He was elected a Fellow of the Society on 1855 April 13.

Charles Clement Walker was born in Clerkenwell in 1822, and was educated in London. He served his apprenticeship as a marine engineer, and later joined his brother, the late Mr. William Walker, in the construction of gas-work machinery, first in Clerkenwell and afterwards at Donnington. The business prospered greatly under the management of the brothers, and the works at Donnington now find employment for some 700 men. The firm have carried out some of the largest structures for the purification and storage of gas in this country and abroad. Mr. Walker was liberal in devoting his wealth to public and charitable objects—as, for instance, in the laying out of Wilmington Square and Northampton Square, in Clerkenwell.

Mr. Walker was one of the oldest readers at the British Museum, having obtained a reading-ticket at the age of 18, and scarcely ever missed an opportunity of visiting the Museum when he came to London. He had a telescope at his residence, Lilleshall Old Hall, and astronomy was his favourite study.

He died on 1897 February 4, from pneumonia and prostration following a severe attack of influenza.

He was elected a Fellow of the Society on 1879 March 14.

Wilhelm Döllen was born at Mitau, 1820 April 25. He there received his earliest instruction, chiefly from his father, who was principal of an excellent school; and at a very early age the exceptional ability of the boy, especially for mathematics, was made manifest. When he was 14 years old, his whole family removed to Dorpat, where he was introduced to the celebrated mathematician Bartels, who soon satisfied himself of Döllen's powers, and advised him, notwithstanding his youth, to attend the mathematical lectures at the University in the following year. From 1836 onwards Döllen also attended the astronomical lectures of W. Struve, with whom and whose family he, from this time, remained on the most intimate terms. According to the statutes Döllen could only be received as a student in the University in the summer of 1837, on attaining the age of 17, but he completed his course in the spring of 1839, and gained his degree with honours in mathematics. Immediately after this he was appointed assistant in the Dorpat Observatory, and remained for five years in that capacity, during which time he

undertook to carry to completion the determinations of positions of double stars by means of the meridian circle, which work had hitherto been carried on by W. Struve and Preuss. The result of this labour was published at a later date in one of the volumes of the Dorpat Observations, and forms an important part of W. Struve's well-known *Stellarum compositarum Positiones mediæ.* To this lengthened stay in Dorpat Döllen was especially indebted for that thorough acquaintance with all departments of human knowledge which distinguished him in later life.

In the spring of 1844 Döllen was appointed supernumerary assistant at the Observatory of Pulkowa. In this capacity he took a most zealous share in the great chronometer expedition between Altona and Greenwich, by which the longitudes of Continental observatories from Greenwich were ascertained for the first time with a fair amount of precision. Döllen gratefully remembered for the rest of his life the kindly courtesy and helpful advice of Airy during his long stay at the Royal Observatory, Greenwich. Three years later, in 1847, a vacancy occurred for an assistant at the Pulkowa Observatory, and Döllen was formally appointed. In this position (excepting only that he was subsequently promoted to the rank of Älter-Astronom) Döllen remained without interruption until the year 1890. Several times during this long period of time he acted as Director, during the latter's absence from illness or other causes.

The first of Döllen's own individual work, which had for its title "Neue Reduction der Königsberger Declinationen für 1820," appeared in 1849 in the *Memoirs* of the St. Petersburg Academy of Sciences. Some years previously he had been attracted by the then little regarded suggestions of Gauss for map-projections, and had constructed, not only convenient formulæ, but tables for their practical application. In consequence of this work, the Gaussian method of projections was in 1847, at the suggestion of W. Struve, introduced into all the cartographical work of the Russian General Staff. Some special researches of Döllen were published by him in 1853 in a separate work, under the title of *Meletemata de Methodis secundum quas superficies delineantur.* In the same year (1853) there appeared Döllen's well-known discussion, in the *Bulletin* of the St. Petersburg Academy, under the title, "Ueber Dr. Wichmann's Bestimmung der Parallaxe des Argelander'schen Sterns (Gr. 1830)," which excited general attention, not only by its sharp criticism of the above-mentioned determination, but also by its comprehensive and searching discussion of the sources of error in observations made with the heliometer. This discussion, moreover, was of the highest value in urging on those improvements in the construction and use of the heliometer by which this instrument has attained its present position as the finest astronomical instrument of precision.

In 1855 Döllen was appointed Professor of Geodesy and

Surveying, his students being the military and marine officers who spent the regulation two years in these studies at Pulkowa. This position not only afforded him an opportunity of exercising his exceptional powers as a teacher (so that we have him to thank for the series of splendidly trained geodesists who, during the decades 1860–90, conducted the geodetic and geographical work of Russia, and brought it to so high a degree of perfection), but also drew his special attention to researches on the methods of observation employed and the construction of the instruments to be used in the work. Amongst his numerous contributions to this subject, the two most important papers appeared in 1863 and 1874, under the title of *Die Zeitbestimmung vermittelst des tragbaren Durchgangsinstruments im Verticale des Polarsterns*, which have made this excellent method for the determination of time widely known and adopted in practice. His work in this direction has been completed by the Ephemerides which he regularly computed and published from 1886 till the time of his death.

It was only in the first few years that Döllen took an active part in the special astronomical observations at the Observatory of Pulkowa. So early as the autumn of 1850 he had a severe attack of typhus fever on which pneumonia supervened. His strong constitution carried him through the sickness, but during the rest of his life he was subject to chronic lung trouble, which necessitated his taking the greatest care to avoid catching cold, to which the observing astronomer is so liable. Before this he had made observations with the Repsold Meridian Circle for the completion of the Pulkowa Catalogue (Epoch 1845) of all stars down to the 6th magnitude. Later he carried on the fundamental determinations of declination with the great Vertical Circle ; but he soon found it necessary to discontinue the work, his weak health compelling him to give up night work. He accordingly occupied himself the more zealously in day observations with portable instruments, in order to examine and develop the various methods of observation for the purpose of determining geographical position. These studies naturally gave him various ideas for improving the construction of the instruments used in this kind of work, which have been duly regarded by the best instrument makers, particularly the Repsolds.

By the advice of his physician, Döllen on two occasions passed the winter in Africa—in Algeria during 1866, and in 1874 in Egypt. These two journeys at the same time afforded him an opportunity of observing the transit of *Venus* at Thebes, in company with Professor Auwers, and of working jointly with Dr. Gill at the geography of those regions.

Soon after Otto Struve left Pulkowa, in the beginning of 1890, Döllen retired completely into private life, and chose for his abode Dorpat, the spot he had loved from early youth. Even here, although freed from all official obligations, he could not be idle. He was especially desirous of assisting in the further

development of nautical astronomy, which science has scarcely made any progress, beyond improvements in the chronometer and compass observations, during the course of the present century, whilst the extraordinary increase in navigation evidently demands more exact determinations of a ship's place at sea than the methods previously in use. With this object in view, in 1893 Döllen published an appeal for assistance in his endeavour, and only a few weeks before his death he published a pamphlet under the title "Zur Reform der Nautischen Astronomie, Tabulæ Dorpatenses," with convenient formulæ based on Sumner's method, and gave the requisite tables calculated for a determinate latitude (58°–59°).

In the foregoing notice only the most important of Döllen's publications have been mentioned. He displayed his greatest activity indirectly as a teacher and a critic of the work of others. During his forty-five years of official life at Pulkowa almost all the work of the Observatory was influenced by his spirit and his extensive knowledge. He was the general arbiter in scientific questions. In such ways as these he essentially contributed to the prosperity of the Pulkowa Observatory under the directorship of the two Struves.

Döllen in 1848 married Charlotte, the eldest daughter of W. Struve, and spent with her forty-six years of happy married life until the time of her death in 1894.

After his retirement from official work, in 1890, it became clear that there was not only lung-trouble but weakness and ossification of the heart, which eventually brought on his death, 1897 February 16.

He was elected an Associate of the Society on 1882 November 10.

Friedrich August Theodor Winnecke was born on 1835 February 5, at the village of Gross-Heere, near Hildesheim, in Hanover, where his father was pastor. A few days after his birth his mother died, and the charge of the child devolved upon his two aunts. His father, who suffered so keenly the sudden death of his wife, resigned his parsonage after a few years. At the age of five young Winnecke was established in the home of his relations at Gittelde, in the Hartz, and later on at Hoya, where he was educated at the Gymnasium till 1850, when he went to the Lyceum at Hanover. Leaving that school when he was eighteen, he entered the University of Göttingen, and devoted himself to astronomical and mathematical studies. He had already shown great inclination in that direction while at school at Hanover by diligently observing the heavens with such small instruments as were available. At Göttingen, in company with Pape, he made observations of comets with a comet-seeker of 34 lines aperture, and determined their places with a ring micrometer. It is interesting to note that at Göttingen Winnecke aroused the enthusiasm for astronomy of the present Professor

Auwers, who was then a pupil at the Gymnasium. The illustrious Gauss, who, on account of old age, had ceased delivering lectures, took great interest in the young and capable student at the University, and it was he who sent Winnecke's first communications to the *Astronomische Nachrichten.*

In the autumn of 1854 Winnecke went to the Berlin University, where in 1856 August he took his degree as Doctor of Philosophy. His dissertation, dedicated to Encke, was entitled "De stella η *Coronæ Borealis* duplici"—a work which at once showed at this early age his sound knowledge of theoretical and practical astronomy.

In this period of his academical career he displayed very great devotion to his studies, observing and computing night and day, while attending the University lectures and elaborating his dissertation, to which the volumes 38–44 of the *Ast. Nach.* bear witness; and his capacity for work is well shown by his determination of the diameter of *Mars* with the heliometer, and his double-star observations with the 9-inch refractor.

Attracted by the fame of that great master of practical astronomy, Argelander, Winnecke in 1856 November went to the Bonn Observatory, where he was most favourably received. Here he remained till 1858 May, displaying throughout that time great and versatile activity, recorded in his papers in vols. 45–48 of the *Ast. Nach.* The 6-inch heliometer had been used up to that time as a telescope with an undivided object-glass. Winnecke investigated it as Bessel had done with the Königsberg heliometer, and he made an extensive series of measures of the principal stars in the cluster *Præsepe*, and with it he also determined the parallax of the star *Ll.* 21185, and of the nebula *h.* 2241. Besides this, he was intent on observing comets, and it was at Bonn that he discovered a periodical comet. He also devoted much attention to variable stars, his interest in which had been excited by the fascinating influence of Argelander.

That period of successful labour, which in after years he looked back upon with so much satisfaction, did not last very long. Wilhelm Struve was a master in discovering men whose intellectual capacity fitted them for attacking certain problems. On his visit to Bonn in the autumn of 1857 he soon perceived the great advantage it would be to the Pulkowa Observatory to have the co-operation of Winnecke, and the invitation he made to him to come to Pulkowa, which was a great honour, was accepted by Winnecke, and accordingly in 1858 May he quitted Bonn. In a short time he advanced from the position of an assistant to that of senior astronomer, and finally to the position of Vice-Director of the observatory.

At Pulkowa his great industry in using the refined instruments of that observatory was unprecedented, and exercised an immense influence not only upon the staff but upon all astronomers who visited the observatory. The Repsold Meridian Circle engaged most of his attention, and the observations he

made with it, extending from 1858 September to 1864 October, form a large part of the first Pulkowa General Catalogue of Stars.

In order to test the accuracy of Encke's value of the solar parallax, determined nearly forty years previously, Winnecke proposed in 1862 an elaborate programme for meridian circle observations of *Mars* at the approaching opposition, which was successfully carried out ; and by combining the Cape observations with his own he arrived at a value of 8″·964 for this constant, proving that Encke's value was too small.

Winnecke's careful investigations on the nature of the great comets of 1858 and 1862 with the 7-inch heliometer and the 15-inch refractor are well known. Many observations of comets, nebulæ, and variable stars made by him in this period will be found in vols. 49–60 of the *Ast. Nach.* In 1864 he temporarily undertook the Directorship of the Pulkowa Observatory during the serious illness of the Director, Otto Struve. It was during this period also that he entered into friendly relations with many English astronomers, especially with Sir George Airy, and he was a member of the Himalaya eclipse party which went to Spain in 1860. In 1864 he paid a second visit to Greenwich for the purpose of examining the old Bradley instruments and MSS.

In 1864 May Winnecke married the niece of Otto Struve. But soon a cloud overshadowed the happiness of his married life. He began to feel the effects of an illness contracted on a voyage, and of over excitement, produced partly by the excessive mental strain of the previous ten years, partly by the weight of responsibility on one so young in the extensive administration of a large observatory, and perhaps also by an attack of acute terror experienced when working one night with the meridian circle. Finding it in vain to obtain recovery from visits to various health resorts, he, in 1865, sent in his resignation, and placed himself under the treatment of Dr. Hertz, at Bonn, where, by the year 1867, his health was completely restored. He now established himself at Carlsruhe with his wife's relations, and by degrees was able to resume some astronomical work. The Grand Duke Frederick of Baden graciously granted him the use of an observatory in the Erbprinzen Garten, and he had some rooms in the small castle, where he was able to observe with some small instruments. Later on he took part in the preparations for the transit of Venus expeditions.

Satisfied with his work, and encouraged by the prospect of renewed happiness, his health greatly improved, so much so that in 1872 he was called to Strasburg to fill a professor's chair and to establish the new observatory that was proposed to be founded there. His old activity at once returned, and he worked hard at elaborating his proposals for the erection of the observatory. He was also much occupied in training astronomers in the necessary investigation of the four heliometers which were to be employed at the forthcoming transit of Venus in 1874.

Eminent as he was in research, he displayed now an equal mastery in the art of teaching. His excellent methodic lectures on astronomy at the university, and his instructive scientific discussions, were most inspiring, ever suggesting independent working in theoretical researches, and in the practical use of instruments. Though he was heart and soul an observer, his mathematical ability made him a master in theoretical investigation, which he enunciated clearly and tersely. His enthusiasm for astronomy, and his unrelaxing energy in utilising every available hour of the night when the sky was clear, made him a conspicuous example to inspire and imitate. With all his superiority and scientific eminence and many-sided knowledge, he was gifted with refined modesty. If asked a difficult question, he requested a short time to consider it, and to consult the literature of the subject, with which he had an extraordinary acquaintance, and then he always delivered an exhaustive explanation.

In 1880 the new observatory, furnished with the largest and best instruments, and admirably constructed in every way, was finished, and in November of that year he was installed. In this year Winnecke was invited to fill the professor's chair for astronomy and to direct the observatory at the Munich University, as successor to Lamont, but the Government induced him to decline it.

The preliminary work for the various proposed investigations at Strasburg was commenced, when in 1881 January 13 he was plunged into affliction by the death of his eldest child, a highly capable and amiable boy. It might be that the absorbing interest of completing the observatory before the meeting of the Astronomische Gesellschaft at Strasburg, which was fixed for 1881 September, and which he accomplished with so much success, kept him up, and thus delayed the sad catastrophe dreaded by his friends; nevertheless in 1882 January, just when his colleagues had elected him rector of the university, and a year after the sad death of his child, the melancholy power again took possession of him. He resolved immediately to put himself under the care of Dr. Hertz at Bonn, hoping, like his family and friends, that the sympathetic treatment of that experienced physician might be able to ward off once more his impending fate. Unhappily all treatment was unavailing, and darkness settled on his great mind uninterruptedly for sixteen years, till 1897 December 2, when he peacefully died.

By his numerous important investigations in various branches of astronomy, published in the *Astronomische Nachrichten*; in the *Monthly Notices*; in the *Vierteljahrsschrift der Astronomischen Gesellschaft*; in the *Bulletin* and *Mémoires de l'Académie de St.-Pétersbourg*; and in the Pulkowa publications; and by the erection and establishing of the Strasburg Observatory, Winnecke has founded a permanent memorial of his illustrious place as an astronomer.

As he was many-sided in astronomy, so he was well acquainted with other branches of natural science, especially geology and mineralogy, in which he took great interest and worked at practically. His versatility and his humour made him a most genial companion. His love of truth, his loyalty, and the gentleness of his mind made him a highly esteemed and beloved friend ; and his trustworthy judgment and extensive knowledge contributed to his excellence as a teacher and a scientific man.

He was elected an Associate of the Society 1863 November 13.

[The council is indebted to Dr. Ernst Hartwig for this notice.]

Proceedings of Observatories.

The following reports of the proceedings of observatories during the past year have been received from the Directors of the several observatories, who are alone responsible for the same :—

Royal Observatory, Greenwich.

With the transit circle 11,416 observations of transits and 10,614 of zenith distances were made in 1896. The total number of stars observed is 5047. About 4000 of these stars are within 26° of the pole and are the reference stars for the Astrographic Catalogue. The remaining observations were of planets, Moon culminators, or for determination of clock error, azimuth, zenith point, &c.

The Moon was observed 103 times with the transit-circle ; the mean error in R.A. of Hansen's *Lunar* Tables with Newcomb's corrections as deduced from these observations is $-0^{s}\cdot154$. The errors for the years 1883–97 are as follows :—

	s		s		s
1883	+0·031	1888	+0·090	1893	+0·034
1884	+0·018	1889	+0·010	1894	−0·016
1885	+0·024	1890	+0·020	1895	−0·066
1886	+0·029	1891	+0·079	1896	−0·088
1887	+0·059	1892	+0·083	1897	−0·154

The number of reflexion and direct observations of zenith distance of stars made during the year was 525. The apparent correction to the *Nadir* observation deduced from these is $-0''\cdot27$. For the years 1890 to 1897 the corrections are $+0''\cdot08$, $+0''\cdot07$, $-0''\cdot25$, $-0''\cdot34$, $-0''\cdot27$, $-0''\cdot26$, $-0''\cdot34$, and $-0''\cdot27$. As stated in last year's report, the screw of the telescope-micrometer was found to be worn and observations were made in January to determine the amount of wear. The intervals of the screw $12^{r}-20^{r}$, $16^{r}-24^{r}$, and $20^{r}-28^{r}$, were compared with $5'$ on the circle, which is approximately 8 rev. of the screw. Further, the intervals $12^{r}-16^{r}$, $16^{r}-20^{r}$, $20^{r}-24^{r}$, $24^{r}-28^{r}$ were compared with

a definite length on the south collinator ; the intervals 16^r-18^r, 18^r-20^r, 20^r-22^r, 22^r-24^r, were similarly compared ; the single revolutions from 16^r-24^r, were similarly compared. The combination of these observations gave the following corrections to be applied to the adopted equivalents of the readings of the screw :—

12r	16r	17r	18r	19r	20r	21r	22r	23r	24r	28r
+1″·39	+0″·80	+0″·52	+0″·35	+0″·16	0″·00	+0″·02	+0″·07	+0″·20	+0″·32	+1″·10

These corrections were applied to the observations made in 1896 whenever the correction amounted to 0″·10, and to all the observations of 1897.

The application of these corrections reduced the discordance of the *Nadir* observations for 1896 from −0″·43 reported last year to −0″·34 given above.

Since the middle of 1895 July, three observations of the *Nadir* have been made on a large number of days. Grouping the observations according to the time of day at which they were taken, the following changes of zenith point are shown :—

	9h–15h.	15h–21h.	21h–3h.
	″	″	″
1895	+0·29	0·00	+0·27
1896	+0·20	0·00	+0·16
1897	+0·15	0·00	+0·17

The R—D discordance for the year is much smaller than it has been for many years. The series of observations of zenith distances of pairs of stars in which one star is observed directly and the other by reflexion alternately on alternate nights has been continued, and forty-three pairs have been observed during the year.

Considerable progress has been made with the ten-year catalogue for 1890. The observations have all been entered from the ledgers for different years on separate sheets for each star, and the precessions and secular variations have been computed and applied. In addition the means have been taken and the catalogue place for 1890 deduced for the clock stars and for 632 *Berliner Jahrbuch* stars which were requested by Dr. Auwers for use in the formation of a fundamental catalogue on which he is engaged.

With the altazimuth forty-three observations of the Moon in the first and last quarters were made during the year.

The new altazimuth when first erected showed anomalous circle readings depending on the direction in which the instrument was last turned. Experiments made under Mr. Simms' direction indicated flexure of the axis, this was corrected by the insertion of a diaphragm in the central part of the instrument. The method of relieving the weight of the instrument was also changed. Instead of friction rollers resting on springs which

pushed the instrument upwards, live rings were put round the axis near the pivots, and these are fastened to springs which tend to pull the instrument upwards. The discordances in the microscope-readings have been almost entirely removed by these means, but there still remains a small difference in the readings of the two circles when the instrument is moved by the slow motion, which is near one end of the axis and appears to produce a slight torsion of one circle relatively to the other.

A few trial observations have been made with the instrument, and the determination of the division errors is in progress.

Comet *Perrine* (1897, *b*) was observed on five nights with the Sheepshanks equatorial. Forty-nine occultations of stars by the Moon were observed by one or more observers, and thirteen phenomena of *Jupiter's* satellites.

With the 28-inch refractor measures were made of distance and position angle of 232 double stars. In all, 492 sets of measures were made, all the observations of one star on a single night constituting one set. Of these stars 72 were less than 0″·5 apart, 61 between 0″·5 and 1″·0, 154 between 1″·0 and 2″·0, and 40 larger than 2″·0. A good series of measures of 70 *Ophiuchi* was obtained, and the following especially interesting pairs which were measured may be noticed :—

	Mags.		Dist.		Mags.		Dist.
			″				″
β 524	5·5	6·5	0·1	ζ *Herculis*	2	6	0·5
β 878	5·8	13·7	1·1	Σ 2525	8	8	0·4
β 883	7·5	7·8	0·3	ζ *Sagittæ*	5	6	0·2
β 552	6·9	10·2	0·4	τ *Cygni*	4	10	0·6
Σ 1639	6·5	8·0	0·2	κ *Pegasi*	4·3	5·0	0·1
Σ 1728	6·0	6·0	0·1	β 733	6	11	0·6

The distance and position angle of the satellite of *Neptune* have been measured on nine nights. The crown lens of the object-glass was reversed from January 12 to April 23, and photographs of the Moon and of the double stars *Castor*, ξ *Ursæ Majoris*, γ *Leonis*, Σ 1606, ζ *Cancri*, and Σ 1877 were obtained.

The erection of the Thompson equatorial was completed in April. The adjustment of the polar axis of the instrument was made at once. Photographs were taken with different separations of the lenses, but it was found that there was a coma in the lateral pencils which could not be got rid of. These photographs were sent to Sir Howard Grubb, who considered it necessary to have the lenses back at Dublin in order to refigure some of the surfaces. Before the object glass was returned some photos of the Moon and double stars were obtained, both in the principal focus and with an enlarging lens. The 30-inch Cassegrain mounted on the other end of the declination axis has been adjusted, and some photographs of the Moon and a few star fields

obtained. The spectroscope has been mounted, but no observations made with it as yet.

With the astrographic equatorial 473 plates with 769 exposures were taken on 117 nights. Of these 91 have been rejected—viz. 27 because the exposure was interrupted by cloud, 18 because the plates did not come up to the standard in showing faint stars, or were too dark for measurement, 24 owing to bad guiding, 18 from miscellaneous defects in the observing or development, and 4 owing to bad plates. Of the 382 successful plates, 248 are for the chart, 120 for the catalogue, 9 typical areas, and 5 for the adjustment of the instrument.

The following table shows the progress of the photo-mapping of the heavens to the end of 1897 :—

	Catalogue.	Chart.
Number of successful fields on 1896 Dec. 31	769	484
Number of successful fields taken in 1897	113	248
Number previously passed, rejected in 1897	8	5
Number of successful fields 1897 Dec. 31	874	727
Total number still required	275	422

Positives on glass of 181 chart plates were made during the year, which with the 358 reported last year, gives a total of 539 plates of which copies on glass have been taken.

During the year 198 plates have been measured, 16 in the direct and 182 in the reversed position in the micrometer. All the plates whose centres are at declination 65°, 66°, and 67°, and the southern halves of those whose centres are at declination 68°, have now been measured in the direct and reversed positions of the plates. The 6^m and 3^m images of each star are measured twice on each plate, so that the positions of the stars generally depend on eight measures, that is, two measures of each image on two plates. Altogether 268 plates have been completely measured.

The measures from 64° to 67° N. declination have been discussed for the personality of measurement. These show that this may amount to about $0''.3$, and that it is almost entirely eliminated in the mean of the direct and reversed measures if made by the same observer.

Copy for press of the measures for zones 65° and 66° has been made, and that for zones 64° and 67° is in progress.

The total number of stars measured in the different zones compared with the number in the B.D. and the A.G.C. are approximately :—

Zone.	No. of Stars Shown on Plates.	No. in B. D.	No. in A. G. C. Cat.
64°	9100	1900	1200 (Helsingfors)
65	8800	2001	844 (Christiania)
66	8600	1684	745 ,,
67	8600	1285	574 ,,

The average number of stars per square degree measured on the plates is 60.

Photographs of the Sun were obtained with the Dallmeyer photoheliograph of 4 inches aperture on 203 days. Of these 409 have been selected for preservation, including 8 with a double image of the Sun, taken to determine the position of the wires with reference to the parallel of declination. Photographs have also been received from India up to 1897 October 27, and from Mauritius up to 1897 August 25, leaving only one day, 1897 February 5, for which no photograph is available for measurement in the year ending with the date of the last Mauritius negative received.

The Greenwich photographs have been measured in duplicate up to 1897 December 2, and the Indian and Mauritius photographs so far as they have been received, with the exception of fourteen Indian photographs. The areas and heliographic positions of the spots and faculæ have been computed very nearly as far as the measurement extends. The copy for press of the daily results is complete for about nine months of the year, except that the spot groups have not been numbered beyond the middle of May. The computations for the ledger are complete as far as 1897 February 14.

The mean daily spotted area of the Sun for 1896, expressed as usual in millionths of the visible hemisphere, is 543, as compared with 974 for 1895, 1282 for 1894, 1464 for 1893, the year of maximum. A rough estimate for 1897 gives 535 for the mean daily spotted area for the year, showing only a very slight difference from the preceding year.

The sun was free from spots on 17 days, and free from faculæ on 6 days, so far as the record is as yet complete. There was a well marked minimum in May and June, the Sun being free from spots for a whole week, May 13–19 inclusive.

The volume of the *Greenwich Observations* for 1895 is printed, with the exception of the Introduction, of which proofs have been received and returned to the printers. The transits, zenith distances and daily Sun-spot results have been printed for 1896.

The north wing of the new Physical Observatory has been occupied since May. Progress is being made with the building of the east and west wings. The electric light is being introduced into the new building. Arrangements have been made for the extension of the telephone from the magnet house to the new building.

Mr. Furner was appointed an Established Computer in November.

The Astronomer Royal left for India on December 13, and Mr. Maunder left on December 8 to observe the total eclipse of the Sun of 1898 January 22.

Royal Observatory, Edinburgh.

The time service, including the daily dropping of the time ball on the Nelson Monument and the firing of the time guns at Edinburgh Castle and at Dundee, as well as the control of several public clocks in the city of Edinburgh, has been carried on, as in former years, under Mr. Heath's charge, the standard mean time clock by Molyneux having been used for this purpose since the removal of the Observatory to Blackford Hill. The observations of time stars have been made with the Dunecht Meridian Circle throughout the year, the satisfactory completion of the roof shutters having admitted of this instrument being brought into regular use in the end of 1896. The 4-inch reversing transit instrument, formerly used for time observations, was dismounted in October.

The clock chamber in the base of the east tower still continues to give some trouble, owing to the escape of moisture from the cement. The Brisbane standard sidereal clock by Dent, being inclosed in an air-tight case, fortunately suffers nothing from this cause. It has been found advisable, however, to dismount the Frodsham clock and temporarily remove it from the chamber. The exposure of calcium chloride in shallow pans is still continued, and the amount of moisture removed in this way appears to be slowly lessening, thus giving some hope that this difficulty will be overcome in time.

The meteorological readings, commenced on 1896 January 1 and fully detailed in the report on the work of that year (*Monthly Notices*, vol. lvii. p. 239), have been regularly carried on. In addition a pair of maximum and minimum exposed black-bulb thermometers were placed in position on 1897 January 1, and have since been read daily. As usual, copies of the daily readings have been supplied to the Scottish Meteorological Society, and abstracts of them are printed in the returns of the Registrar-General for Scotland.

The new reduction of the right ascensions of the stars observed under the direction of the late Professor Henderson has made considerable progress, and continues to show evidence of a satisfactory final result being arrived at.

The bifilar pendulum, with its photographic apparatus for recording earth tremors by the rotation of a suspended mirror, has worked with much regularity throughout the year, the record being nearly continuous. The most remarkable result yet obtained with this instrument was its record of the great Indian earthquake of June 12. A short note descriptive of this record was read before the Royal Society of Edinburgh by Mr. Heath, and an enlarged reproduction of the photograph will be found in vol. xxi. p. 481, of the *Proceedings* of the Society. Since the above date several well-marked disturbances have been recorded. Two of these are clearly identified with the earthquakes of

August 5 in Japan, and Sept. 17 in Turkestan. Another is, with some probability, identified with the earthquake in Peru on Sept. 20.

The Dunecht Meridian Circle was finally placed in position late in 1896. A rigorous examination of the division errors for each degree of the circle was commenced by Dr. Halm, employing Nyrén's method, in 1897 October, and finished before the end of the year. Dr. Halm has also undertaken a determination of the flexure of the instrument. A series of observations of fundamental stars has been commenced for the purpose of testing the accuracy of the determination of the division errors, and of the provisional value of the flexure.

The electric control for the driving clock of the 15-inch refractor was completed by Mr. Ramsay in January, and has since worked satisfactorily. This telescope was employed during the first three months of the year by Dr. Halm in completion of the spectroscopic observations of the planets *Venus*, *Mars*, and *Jupiter*, commenced in the preceding year. In April Dr. Halm began a new series of observations of the chief lines in the brighter planetary nebulæ.

A grant placed at the disposal of the Astronomer Royal for Scotland by the Joint Permanent Eclipse Committee, enabled him to arrange an expedition to India to observe the total solar eclipse of 1898 January 22. Preparations for this purpose were commenced in September, all the apparatus to be taken to India being mounted for adjustment, and the necessary computations made by Mr. Ramsay. When the whole equipment was complete and packed, the boxes were shipped for India in the middle of November. Professor Copeland and Engineer Macpherson started from Edinburgh early in December.

Only one of the *Edinburgh Circulars* was issued during the year—No. 52—containing an ephemeris of *Comet Perrine* (1896 November 2) by Dr. Otto Knopf, of Jena.

The laying-out of the grounds about the Observatory, a much needed improvement, was begun by H.M. Office of Works in November, and is still proceeding.

An extension of the electric light installation to the outlying Observatory buildings was carried out by H.M. Office of Works in July.

Royal Observatory, Cape of Good Hope.

The Lords Commissioners of the Admiralty and of H.M. Treasury have favourably considered the representations made by H.M. Astronomer both in regard to an increase of staff and the provision of a new reversible transit circle, with an observatory suitable for fundamental work.

Mr. W. H. Finlay, M.A., has been promoted to the rank of chief assistant, Mr. J. Lunt, B.Sc., has been appointed assis-

tant, chiefly for work connected with the McClean telescope. Messrs. Pett and Cox remain as second-class assistants (old establishment). Messrs. Power and Woods become established computers, higher grade ; Messrs. Pead, Woodgate, Goodman and Cochrane are added to the staff as established computers. Mr. R. T. A. Innes has been appointed on the permanent staff for secretarial duties.

The details of plans for the new transit circle have been fully discussed and finally settled ; a contract for the completion of the instrument by the end of 1898 has been arranged with Messrs. Troughton & Simms. Plans of the new observatory for this instrument have been made at the Cape, and tenders for its construction have been called for by the Admiralty.

The MS. of definitely reduced Cape observations of comets 1879–94 has been forwarded for printing. This will form Part 1, vol. i. of the Annals of the Cape Observatory—instead of a history and description of the observatory, for which this place was originally reserved.

The page-size of vol. i. (demy quarto) having been found too small for many purposes, and especially for an illustrated description of the observatory, a royal quarto size was adopted for vol. ii. and all succeeding volumes of this publication. A new title page to Part 2 of vol. ii. (which was printed before the change of size was decided upon) will be issued, to convert this part into Part 5 of vol. i.

Volume ii. will contain, besides Part 1 already issued :

Part 2. A complete catalogue of known Southern double stars.

Part 3. Observations for change of latitude with the Zenith telescope.

Part 4. Results of general observations with the Zenith telescope.

This volume will probably be completed during 1898.

A history and description of the observatory is relegated to a future volume so as to include an account of the McClean observatory and of the new transit circle.

Volume iii. of the Cape Annals (being part 1 of the Cape Photographic Durchmusterung) was completed last year.

Volume iv., being Part 2 of the same work, and containing the places and magnitudes of 158,000 stars, derived by Professor J. C. Kapteyn from the Cape photographs between the limits of declination $-38°$ and $-52°$ (both inclusive) has been passed through press.

Volume v., Part 3 of the same work:—the MS. has been forwarded for printing as far as Decl^{n} $-60°$, and Professor Kapteyn reports that the remainder of the MS., carrying the work to the South Pole, is nearly ready, and will be complete long before the work as far as $-60°$ has been passed through press.

Volume vi. Part 1 of "A Determination of the Solar Parallax and Mass of the Moon from Heliometer observations of the

Minor Planets *Iris*, *Victoria*, and *Sappho*." The final sheets were passed for press on March 18, but the volumes were not delivered at Greenwich for distribution till November 16.

Volume vii. Part 2 of the above, was completed in 1896, and it will be distributed with its sister volume.

The meridian observations, made under the direction of Sir Thomas Maclear 1860–65 and recently reduced, have been printed, and should be ready for distribution. The reductions of the remaining part of this work, 1866–70, are well advanced.

The greater part of the Cape 10-year Catalogue of 3007 stars has been passed through press. The preparation of the introduction has been somewhat delayed by an elaborate comparison which has been made with other catalogues.

A separately bound appendix to the meridian observations 1890–91 containing the new Cape star-reduction tables by Mr. Finlay is ready for distribution, as also are the meridian observations 1892–95.

Copies of the independent day numbers, 1897, for use with the star-reduction tables were distributed from the Cape in May last. The corresponding day numbers for 1898 have been passed through press and advance copies sent to the chief observatories. The MSS. of the day numbers for 1899 and 1900 have been forwarded for printing.

The work of the present transit circle has been confined to observations of the standard stars required for the reduction of the international "Catalogue plates." The whole of the standard stars for the zone $-40°$ to $-43°$ (both included) have been observed at least 5 times each. This list provided a minimum of 10 well distributed stars for each plate.

The observations made with the transit circle during the year have been :—

Transits	9371
Determinations of Z. D.	8743
,, Collimation	97
,, Level	331
,, Azimuth	267
,, Run	325
,, Nadir	312
,, Flexure	43
Obs. of Meridian Marks in Azimuth ...	162
,, ,, in Z. D.	37

Of these observations :—

The computations of Mean R.A. are complete to 1897, December 1.

The computations of Mean N.P.D. are complete to 1897, October 27.

Ledger prepared to 1897, April 7. Apparent N.P.D. to 1897, December 31. Star corrections to 1897, December 31.

The selection of the Standard Stars for the remainder of the Cape Catalogue plates is nearly complete. The working list for 1898 is prepared from 0^h to 18^h. By diminishing the number of observations of each star to three or four, and observing when necessary in double watches, it is proposed to complete the meridian observations of the Standard Stars for the remainder of the Cape Zones, viz. from 44° to 51° (both inclusive) by the end of 1899, so that the observers may be at liberty to take up fundamental work with the new transit circle in 1900. The whole will constitute a catalogue of over 9000 Standard stars between Dec. −40° and −52°.

Observations of 152 separate phenomena of occultations were obtained as follows :—

	D.D.	R.D.	D.B.	R.B.	Total.
Predicted by the N. A. office	26	13	2*	...	41
Daylight Occultations of *Antares*	...	1	...	...	1
Miscellaneous occultations	107	2	1	...	110
*η Piscium and Antares			Total	...	152

Of these phenomena, three were observed by three observers, and twenty-one by two observers each.

Comet I. 1897 (*Perrine*) has been observed on eight nights by Mr. Finlay, with the 7-inch equatorial. The results have not yet been published.

Mr. Innes has been chiefly occupied in the revision of four lists of stars communicated by Professor Kapteyn in 1896 December.

I. 90 Stars contained in catalogues of precision and missing in the C.P.D. between Dec. −38° and −53°.

II. 247 Stars of mag. 9·0 or brighter, contained in Thome's Durchmusterung, and missing in the C.P.D. between Dec. −22° and −34°.

III. 19 Stars, mag 9·2 or brighter, contained in the C.P.D., and missing in Thome's Durchmusterung, Dec. −22° to −34°.

IV. 7 Stars suspected of variability.

All these stars have been under revision, many of them a great number of times. In no case has any error in the C.P.D. been found. The most interesting result has been the discovery, (*Ast. Nach.* 3464) that the 8th mag. star, Z.C. V^h. 243 (1875·0) $5^h\ 6^m\ 40^s - 44°\ 58'$ has the largest proper motion of any yet known, being nearly 9″ of arc on the great circle per annum.

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The following stars, in addition to the lists published *Ast. Nach.* 3426 and 3441, have been proved variable :—Equinox 1875.

h m s	° ′	
9 3 48·6	−28 29·7	Th. 8·8 : C.P.D. 10·2, found certainly variable. 9·0 to 9·8, period 250 to 300 days.
6 49 33·2	−24 0·6	C.P.D. 8·6 : visually variable 8·7 to 9·3, no period recognisable.
19 56 25	−55 54·2	C.P.D. 9·0 to below 10·4, has been noted 11·5 till below visibility.

About 20 suspected variables are still under observation, and a number of errors in other catalogues have been traced.

Partly in connection with this work, and partly as the result of special search, Mr. Innes has found 128 new double stars, excluding those which had been previously discovered, and were by oversight entered in discovery-lists, and also pairs found previously, and almost simultaneously by Professor See in Mexico.

Of these new pairs	61	are under	1″	
,, ,, ,,	36	,, between	1″	and 2″
,, ,, ,,	24	,, ,,	2″	and 5″
,, ,, ,,	7	,, ,,	5″	and 10″

Stars of the last class consist of a bright star with very faint companion.

Those found previous to 1897 March 24, are published *Ast. Nach.* 3419.

Those found previous to 1897 June 30, are published *Ast. Nach.* 3438.

Those found previous to 1897 Oct. 13, are published *Ast. Nach.* 3462.

In course of this work, the need of a complete catalogue of all known double stars south of the Equator has been constantly felt, and since his arrival at the Cape, Mr. Innes has devoted his spare hours to its preparation. The work is now complete to the end of 1897, and it is proposed to print it in Volume ii. of the Annals.

On nights of bad definition, Mr. Innes has searched for Comets without direct success, but has noted several uncatalogued nebulæ, of which particulars will be communicated to the Society.

Two young observers, Messrs. Goodman and Löwniger have been trained in the use of the Heliometer, and plans have been made for systematic heliometer observation of all the major exterior planets near each opposition. The comparison stars necessary for this purpose have been selected for all the oppositions till the year 1900 inclusive. A printed list of these stars will be shortly circulated, and the co-operation of Astronomers provided with good meridian instruments is earnestly invited for their observation.

To increase the accuracy of the results of meridian observations, steps have been taken to connect by Heliometer triangula-

tion the whole of the stars which will be employed at the opposition of each planet. It frequently happens that a number of different oppositions may be observed, in which all the comparison stars employed may be connected together in the same system of triangulation. Thus for example, we have:

Triangulation I., connecting together the thirty-six stars which are required for Heliometer observations of the oppositions of

Uranus in May 1898, 1899 and 1900.
Saturn in May 1898.
Jupiter in May 1900.

Triangulation II., which connects together nineteen stars required for Heliometer observations of *Neptune* in 1897, 1898, 1899 and 1900.

A triangulation of twenty-one stars in the neighbourhood of the South Pole has been arranged, the object being to combine Heliometer observations of their mutual distances with all existing meridian observations of the brighter stars situated within about 2° of the pole and to form definitive plans of them for the Equinox 1900.

The following observations have been made with the Heliometer since work was systematically commenced in July.

Of the eighty-three pairs of stars measurable in Triangulation I., every pair has been observed at least once either in position-angle or distance; there have in all been made in this triangulation—

103 observations of distance.
63 „ „ position-angle.

Of 122 measurable distances in the South Pole Triangulation, forty-one pairs have been observed twice, and ten pairs once. As this work can be continued at any season of the year, it is reserved to fill the observer's time when other work is not pressing.

The above numbers do not include the observations of the standard stars in each triangulation. The standard stars are observed at the beginning and end of each night's work, or if more than three or four pairs are observed, the standard stars are also measured in the middle of the work.

Nine complete sets of observations were obtained of the planet Neptune at last opposition. In each set the angular distance of the planet from four symmetrically situated comparison stars was symmetrically measured. Each set of observations thus consisted of thirty-two pointings. Very extensive co-operation on the part of meridian observers will be necessary to secure an accuracy in the places of the comparison stars corresponding in any degree to the precision with which the position of the planet relative to these stars is thus determined.

A few Heliometer observations connected with stellar

parallax, double star, &c., have been made by Dr. Gill and Mr. Finlay. The reductions of the 7-inch Heliometer observations for parallax of the principal southern stars have now been taken up, and the following series have been definitively discussed and prepared for press :—

Star.	Parallax.	Prob. Error of π.	Prob. Error of the Single Obs.	Mag. of the Comp. Stars.	Observer.
	″	″	″		
β Orionis	0·000	±0·010	±0·060	8·4 and 8·5	Gill
β Centauri	+0·046	±0·017	±0·084	8·0 „ 8·0	„
Sirius	+0·370	±0·0097	±0·070	8·7 „ 8·7	„
Canopus	0·000	±0·011	±0·073	8·5 „ 8·5	„
α Gruis	+0·015	±0·007	±0·042	8·0 „ 8·0	„
Antares	+0·021	±0·012	±0·084	6·5 „ 8·0	Finlay
Fomalhaut	+0·130	±0·014	±0·075	8·5 „ 8·5	Gill

In the column "Prob. error of the single observation," the probable error given is that of the *difference* of the two opposite distances measured. The probable error of the *locus* of the principal star projected on the great circle joining the two comparison stars is therefore half of the quantities given above.

The reductions of the following series are far advanced :— Observer Gill, *α Crucis*, *β Crucis*, *β Hydri*, *α Eridani*, *α Virginis*. Observer Finlay, *ε Orionis*, *Canopus* (2nd series), and *β Crucis* (2nd series). Of these only *β Hydri* appears to have considerable parallax. The complete memoir containing these discussions will probably be printed in Volume viii. of the *Cape Annals* in the course of the year 1898.

Regular observations with the zenith telescope have not yet been resumed, as the origin of some anomalous results in former series have not yet been completely traced. A preliminary note, prepared by Mr. Finlay, on the Change of Latitude, and on the Constant of Aberration, from observations by Gill and Finlay, 1892–94, has been communicated to the Society. The complete work is in preparation for press, and will appear in Volume ii. of the Annals. In the years 1886–91 436 pairs of stars were observed with the zenith telescope, as a rule on six nights each. These observations have been reduced during the year, and the results will also appear in Volume ii. of the Annals. As the stars which compose these pairs are all contained and well observed in the *Cape General Catalogue* for 1890, and as they are all symmetrically distributed in R. A. and Dec., and the northern components of the pairs have all been observed by Dr. Romberg, and will appear in the next *Pulkowa Transit Circle Catalogue*, these observations become of considerable interest in connection with the determination of fundamental declinations.

To H.M. Astronomer and every member of the staff, one of the most interesting events of the year was the visit paid by

Mr. McClean to the Observatory, where he lived and worked from the middle of May to the end of August. In September and October he was joined by Mrs. McClean with other members of his family, and resided in another suburb of Cape Town, but Mr. McClean visited the Observatory nearly every day and every clear night. The normal work of the astro-photographic telescope was suspended on April 20 in order to attach the mounting of Mr. McClean's 20° objective prism of 12 inches aperture to the instrument, and to make preparatory arrangements for balancing the telescope. Thus, within a few days of his arrival the prism which Mr. McClean had brought with him was mounted and counterpoised, and he commenced the completion of his spectrographic survey of the heavens to stars of $3\frac{1}{2}$ magnitude by making pictures of such spectra as he could not obtain in the latitude of Tunbridge Wells. Mr. McClean sailed from the Cape in the end of October, having successfully accomplished his principal object. His visit is a memorable one, not only from the scientific results which he secured, but from his constant kindness to all, and the many benefits he conferred on the Observatory during his visit. There is but one regret to record in connection with this visit, viz. that the telescope which the Observatory owes to his liberality did not arrive from Dublin as Sir Howard Grubb led us to expect that it would, and Mr. McClean was thus deprived of the pleasure of witnessing its erection. It is the hope of every member of the staff that Mr. McClean will soon revisit the Observatory and see the telescope we owe to him in full working order. The McClean Observatory itself is completed as far as possible, but until the heavy parts of the stand arrive, the final partition-wall cannot be erected, nor the entrance hall be finished. The rising floor, designed by Mr. McClean and Mr. Osbert Chadwick, and constructed by the Glenfield Company, of Kilmarnock, has been erected by Cape workmen under the supervision of H.M. Astronomer; it works to perfection. The lower portion of the iron pier of the telescope has arrived, and is erected and oriented. It is understood that Sir Howard Grubb has the rest of the instrument now nearly ready for shipment.

Previous to April 20 the following work was accomplished with the Astrographic telescope :—

	No. of Plates.	No. of Exposures.	Duration of Exposure.
Chart Plates	46	138	30^m each
Do. interrupted	6	8	5^m to 30^m
Plates exposed on stars suspected of variability in connection with revision of the C.P.D.	13	15	6^m
	3	3	10^m to 30^m

After October 27 the instrument was readjusted, object-glass and clock cleaned, and sundry repairs and alterations carried

out, and the following plates connected with adjustments were taken :—

Trails for focus	11
Adjustments	11

After which the following exposures were made :—

Charts (even zones)	2	2	40^m and 45^m
„ (odd zones)	26	78	30^m each
Interrupted	3	7	10^m to 30^m
Catalogue plates (repetitions)	24	72	6^m 3^m 20^s
Rejected	1	3	6^m 3^m 20^s
Standard Area	1	3	6^m 3^m 20^s
Plates exposed on suspected variables, &c.	14	14	10^m to 30^m

Very little has been done in measuring the plates pending the new experimental arrangements which have been made for this work. A new instrument for measuring photographic plates, devised by H.M. Astronomer, has just been received from Messrs. Repsold. The new apparatus and methods promise to give even greater rapidity of work than Professor Turner's method, without sacrifice of the accuracy obtained with the older form of the filar micrometer. A description of the instrument, with examples of its work, will be communicated to the Society.

A geodetic survey of Rhodesia has been sanctioned by the Government of the British South Africa Company and placed under the direction of H.M. Astronomer. The selection and beaconing of the points of the principal chain of triangulation is nearly completed.

The time-signal service has been regularly maintained. The meteorological observations made during 1897 have been communicated to the Cape Meteorological Commission.

Cambridge Observatory.

The Cambridge contribution to the *Catalog der Astronomische Gesellschaft* has been published and distributed in the course of the year, It contains the mean places, reduced to epoch 1875·0, of 14,464 stars, each of which has been observed, on an average, about four times. The extreme limits in declination are 24° 15′ and 30° 57′ N., but only few are beyond 24° 45′ and 30° 15′.

The following extract from the Introduction will show the reliance that may be placed in the results.

To obtain the probable errors in right ascension and declination, "it was intended at first to examine all the stars of which five observations and upwards had been taken; but as 916

observations of 141 stars brought the work up only to $0^h\ 50^m$ right ascension, it was thought better to limit the examination afterwards to seven observations and upwards. Two stars only were omitted which gave decided evidence of proper motion; and one observation was rejected which differed in right ascension considerably from the others, while the star was marked in the memorandum-books *very faint*. The final result, from 7461 observations of 945 stars, gives for the probable error of one observation

$$\text{in R.A. } 0^s\cdot06608 \pm 0^s\cdot00040$$

$$\text{in Decl. } 0''\cdot5079 \pm 0''\cdot0031$$

"About 9000 places in this catalogue have been compared with the older catalogues, more especially Weisse's Catalogue of Bessel's Zone Stars, the British Association Catalogue of Lalande's Stars, Rümker's and Struve's Catalogues, the more exact places of stars in the Durchmusterung given in vol. vi. of the *Bonn Observations*, occasionally with Piazzi and Bradley, and in a few cases with the earlier Greenwich Catalogues."

"The results of these comparisons are tabulated in a condensed form, and will be given with a larger edition of the catalogue. This edition," now ready for the press, "will contain the results of the individual observations, with dates and number of wires, and the precessions in right ascension and declination, tables being given from which the secular variations of the precessions may be easily deduced. A very large number of the discordances appear to be due to systematic errors in the zones of Lalande and Bessel. In one instance the places of several stars which were found in two of Bessel's Zones—309 and 323—differ in Weisse's Catalogue, systematically, about $1^s\cdot4$ in right ascension."

A list has been made out of all the stars in the catalogue which have only been observed once, and a few that gave decided indications of proper motion, or about which a question had arisen, comprising 1420 stars. More than half of these have been re-observed with the meridian circle in the course of the year and reduced to epoch, adopting, as in the catalogue, the Berlin places of the standard stars.

The usual precautions have been taken to obtain a sufficient number of observations for clock and instrumental corrections.

Thus the meridian circle has been constantly, and we trust usefully, employed, as far as weather would permit; and the requisite calculations are nearly up to date.

The Northumberland equatorial has been chiefly used in the endeavour to awaken an interest among the undergraduates for astronomical work, by admitting them freely, on Saturday evenings especially, to the examination of the heavenly bodies.

The Newall Telescope, Cambridge Observatory.

The Newall telescope was used for observation on eighty-two nights in the course of the year 1897, the weather having been more unfavourable for observations than in any other year since the instrument was set up at Cambridge.

The work of the year has been almost entirely connected with the determination of velocity in the line of sight, and with the study of special stellar spectra.

The results of the previous year had been found to differ more or less systematically from Vogel's results for many of the brighter stars. The long troublesome search for the cause of the discrepancy—referred to in last year's report—ended in January in the discovery of the fact that the compression of a spring connected with the prisms used for getting the comparison spectra produced a minute deflection of the collimator every time the prisms were used. This defect was easily and immediately remedied, and the work has been carried on without difficulty—except for the unfavourable weather during the year.

A short note was communicated to the Society (*Monthly Notices*, Vol. lvii. pp. 557–577) giving some account of the general method adopted in the work, and pointing out that the chief difficulty in accurate determinations of velocity lies in the identification of a definite line in the middle of a group of lines. A few examples of results are given in the paper, and the velocities determined at Cambridge are shown to be in good agreement with those determined by Vogel, Keeler and Belopolsky.

Dunsink Observatory.

For the first half of the year 1897 the meridian circle and chronograph were used for observing the stars mentioned in the report for last year.

During the year there have been in all 4400 observations made with these instruments. This number includes 106 observations of collimation, 137 of level error, 64 of the nadir point, and 16 of the error of runs of the microscopes. For determining the error of azimuth 74 transits of polar stars have been observed, for the error of the Dent sidereal clock 354 transits of standard stars, and for the equator point of the circle 273 zenith distances of these stars have been observed.

The observations of the working-list stars amount in both R.A. and declination to 1688.

Upon Dr. Rambaut's appointment as Radcliffe Observer at Oxford, systematic observations with the meridian circle (except for determining time) were discontinued, and the interval between July 17, the last day of observation, and the end of the year has been devoted to bringing up arrears of reduction

and preparing for the press all the observations made with the meridian circle during the last two years which are not included in the seventh part of the Dunsink publications. In this work, as well as in the observations upon which it is based, Mr. Martin has displayed the greatest vigour, and has succeeded during the five months from July to December in reducing to catalogue form 4022 observations of 1101 stars.

This work will shortly be published as Part VIII. of *The Astronomical Observations and Researches made at Dunsink.* The probable errors computed in the usual way show that this work is of a high order of accuracy. The probable error

in R.A. as computed from 3473 observations is $\pm 0^s.033$

and

in Decl. as computed from 3397 observations is $\pm 0''.48$

The Roberts equatorial has been used as heretofore for stellar photography, principally in photographing star groups and clusters. The plates containing photographs of *Comet b* 1896 have been completely measured and reduced, and the results published in the *Monthly Notices* for June 1897.

Preparations were made for photographing the *Leonids* of November 13 and 14, using a 5-inch photographic doublet of about 16 inches focal length, with which it was hoped some trials might have been obtained, but unfortunately every night from the 12th to the 16th proved cloudy.

The post of Royal Astronomer of Ireland and Professor of Astronomy in the University of Dublin, which became vacant by the appointment of Dr. Rambaut to be Radcliffe Observer at Oxford, has been filled up by the appointment of Mr. Charles Jasper Joly, Fellow of Trinity College, Dublin, who assumed his duties as Director of the Observatory on December 21.

Durham University Observatory.

The routine work during the past year has been confined to meteorological observations, which have been taken regularly. The fund which has been collected for the purchase of an almucantar to supplant the existing transit circle is now well forward, and the construction of the instrument will be proceeded with as soon as possible.

Glasgow University Observatory.

In the first half of the year the work with the Transit Circle was preliminary in character. It included the determination of the division errors for every degree, those of every fifth degree having been derived in the previous year. The measurements were made by means of a twin-microscope which has two object-

glasses and micrometers and one sliding eye-piece. At the beginning of August the observations of the rectangular co-ordinates of the principal pole-stars and of three stars which are nearest the pole were begun.

The greater part of the time was, however, devoted to the spectroscope which is connected with the twenty-inch Breadalbane reflector. The 60° prism, which measures $6\frac{1}{2}$ inches on the side and $3\frac{3}{4}$ inches high, was returned in February after having been reannealed, and the definition is now as good as can be expected.

Besides the ordinary adjustments of the spectroscope, lengthy experiments were made on the flexure of the apparatus and on methods of getting rid of it. Four object-glasses achromatised for different portions of the spectrum had been supplied for the collimator, in which the ratio of aperture to focal length is one in nine, and the focal curves were worked out from photographed spectra. An object-glass designed for visual purposes gave the best results although the plate has to be inclined 18° between *F* and *G* and 30° in the ultra violet. It was found that the inclining of the photographic plate has no appreciable effect on the definition, indeed the lines of the iron spectrum appear without halo and of such definition that 0·3 Angström units are sharply separated near *H*. During the experiments it became apparent that great changes of temperature in the dome destroy the definition, and that after a sunny day it is impossible to obtain satisfactory results. This is a serious disadvantage attached to the employment of a very large prism.

Since October photographs of the brighter stars were taken with the object of ascertaining the proper length of exposure. Although every opportunity was utilised there were only a few nights available. The weather was exceptionally bad in November and December, and when clear the atmosphere was either hazy or so damp that the mirror and prism became covered with dew. On two occasions *Arcturus* and *Vega* were photographed in daylight, the atmospheric spectrum serving as reference. In other cases iron and calcium spectra were used for comparison. The plateholder is so constructed that its position can be adjusted on an artificial spectral line during the exposure on a star and thus any length of exposure can be given.

Some experiments on the sensitiveness of photographic plates proved that this can be somewhat increased if a thin film of vaseline is spread over it. This action is perhaps due to fluorescence.

It was found necessary, owing to the damp weather, to re-silver the twenty-inch mirror twice during the last three months.

All the reductions have been kept up to date and a series of tables for the reduction of observations, made with the spectroscope, transit circle, and refractor, have been computed.

The time-service and the extensive meteorological work have been carried on as in former years.

Liverpool Observatory.

The instrumental equipment of the Liverpool Observatory remains the same as last year, with the exception that a seismometer has been mounted in the basement, with the co-operation of the Earthquake Committee of the British Association. This instrument, which is a form of bifilar pendulum, has been mounted to record displacements in the plane of the prime vertical. The adjustments were complete in September last, and the record has been regularly maintained since, but no certain indications of movement have yet been registered.

The arrangements for testing the accuracy of chronometers, &c., remain as in former years. About 200 marine chronometers have been under examination at the observatory during the year. The firing of the time gun has been regular and accurate.

The meteorological observations and automatic registrations have been maintained as usual. The Dine anemometer mentioned in the last report works satisfactorily, and an extended series of comparisons between the records of the Robinson and Dine anemometers has been made, and is being still further continued.

The meteorological observations made in the past year have been printed and circulated by order of the Mersey Docks and Harbour Board.

The occultation of the *Pleiades* was fairly well observed on July 23 and again on January 3 of this year with the 8-inch equatorial. The same instrument has been used regularly for the observation of those comets that were sufficiently bright to be observed, and the results will be communicated to the Society as in former years. The circumpolar stars, whose places were published by Professor Auwers in *Astronomische Nachrichten* No. 3440, have been regularly observed in right ascension as frequently as possible with the transit instrument, and the results have been forwarded to him.

Three courses of lectures have been given in connection with the classes at University College, Liverpool, and these have all been well attended.

Radcliffe Observatory, Oxford.

During the year the Observatory has suffered the loss by death of its eminent and distinguished Director, Mr. E. J. Stone, M.A. (Cantab. et Oxon.), F.R.S., who for the last nineteen years has conducted its affairs with such success.

Dr. Rambaut, late Royal Astronomer of Ireland, was appointed to succeed him as Radcliffe Observer, and assumed the direction of the Observatory on October 20. In the interval which elapsed between the death of Mr. Stone in May and his

successor's assuming the duties of Radcliffe Observer in October, the affairs of the Observatory were conducted by the First Assistant, Mr. W. Wickham, on the same lines as in recent years, and the routine work has thus been carried on with but little interruption, notwithstanding the changes which have occurred.

With the transit circle the observation of a zone of stars between the equator and 5° north declination, commenced during the previous year, has been continued ; also the places of many zodiacal stars, not included in the Radcliffe Catalogue for 1890, and which are required for use in the *Nautical Almanac*, have been secured. The Sun was observed on the meridian 36 times and the Moon 45 times ; but since September, owing to pressure of other work upon the staff, the Moon has not been put on the observing list after Full.

The Barclay Equatorial has been used in the following observations : Comet *Perrine* (1896 December 8), observed on two nights ; Comet *Perrine* (1897 October 26), on one night. Various other attempts to secure observations of comets were ineffectual owing to the faintness of the object when seen, or failure to pick it up at all, as in the case of Comet *Brooks*.

The magnitude of *Nova Aurigæ*, which had apparently remained fairly constant at $9\frac{1}{2}$ for the previous four years, was noted on 1897 March 10 to have fallen as low as $11\frac{1}{2}$, and observations made on twenty nights since then have failed to detect any further marked change up to December 31. During the interval May to November the star was not conveniently placed for observation. The occultation of the *Pleiades* by the Moon on July 23 was observed here, and the results have been communicated to the Society. Among the miscellaneous work with this instrument may be mentioned : Observations of the magnitude of B.D. $+51°\cdot244$, which was noted as 9·5 by Argelander (in reality there are two stars of nearly equal magnitude, about 11 mag., and separated from each other by 46″) ; also observations of other stars of suspected variability ; positions of faint comparison stars for comets ; occultation of *Ceres* by the Moon ; examination of nebulæ and red stars.

The heliometer has been used as an equatorial telescope for observing occultations, and, the moving parts having been thoroughly cleaned, a number of observations have been taken as a test of the working of the semi-lenses and of the instrument generally, with a view to judging of its practical value as a measuring instrument during the coming year.

The *Leonid* meteors of 1897 November 13 were observed, and the results are printed in the *Monthly Notices* for December.

The meteorological observations and automatic registrations have been regularly maintained as usual, and the results have been communicated to public institutions as well as to private inquirers. The four platinum thermometers, acquired at the end of the year 1896, have been supplemented by two others ; one has been placed 10 feet below the surface of the soil, whilst the

other has been used in the observing room for comparison with mercurial thermometers and for other purposes. These thermometers and the associated resistance apparatus are exceedingly sensitive and delicate, and certain initial difficulties have been encountered in getting them into working order. The solution of these difficulties and the determination of the fundamental points of the scale for each thermometer have necessarily consumed a large amount of time, but a good deal of light has been thrown on some interesting points connected with them, and it is anticipated that they will prove very useful for determining the seasonal changes of temperature at various depths in the ground.

University Observatory, Oxford.

The measurement and reduction of the Catalogue plates has proceeded throughout the year quite satisfactorily, by the help of the grant of 150*l.* annually from the Government Grant. This is the second year out of the five during which it is proposed to ask for this grant. Four or five computers (of ages ranging from 15 to 18) have been employed on the work at the Observatory, and Mr. Moore, of the Leeds Astronomical Society, has also done a considerable share of measuring.

As stated in the last report, each plate is measured twice over, in reversed positions. A comparison of the figures set down on the two occasions shows that the "errors of bisection" thus eliminated are very small, and might have been neglected, *i.e.* measurements made in one position only are practically good enough; but the measures in the reversed position are most valuable as an independent check on the measures in the first, and will be continued throughout the work. (See *Monthly Notices*, vol. lvii. p. 621, &c.)

During the year 500 plates have been measured in one position or the other, with an average of 290 stars on each, involving the record of 145,000 stellar positions. Since each image is measured twice, and since each star occurs on at least two plates, this corresponds to the cataloguing of about 35,000 separate stars. These large numbers indicate the power of the photographic method.

As regards the reductions, places of the stars observed on the meridian at Cambridge and Berlin have been converted into "standard coordinates" for the whole of zones $+25°$, $+27°$, and $+28°$ (18,000 stars), zone $+26°$ having been done last year. These coordinates have been compared with the measures, equations formed and solved, and formulæ of correction thus obtained for 170 plates.

In the last report a hope was expressed that the measurement and reduction of zones $+26°$ and $+27°$ (360 plates) might be completed by the end of 1897. This has not been found practicable, the above-mentioned 170 plates being all that are

completed, and some of these being in other zones; but about 100 other plates are well advanced towards the final stage. One reason for the falling short in the number of plates expected is that too low an estimate had been made of the number of stars per plate. This was expected to be 200, but the average for the year is 290. Now, this is a serious increase, and if maintained would clearly render it difficult to get the work done in the proposed time. On examination, the increase was found to be in great measure due to the enormous number of stars on plates exposed to the Milky Way. The greater photographic brightness of these has been already remarked by Kapteyn and Gill; a practical result of it is that while the number of stars shown on poorish plates in regions remote from the Milky Way is 2 or 3 times that of Argelander's charts, this ratio may rise to 10, 15, or even 20 for good plates in or near the Milky Way. For instance, on three consecutive plates in $+26°$, R.A. $17^h\ 36^m$, $17^h\ 44^m$, and $17^h\ 52^m$, there were measured 1166, 1379, 1111 stars respectively; Argelander only giving 62, 83, and 98, and the Cambridge Catalogue 44, 39, and 54. Now, there does not seem sufficient reason for measuring all these stars and protracting the work accordingly. A determined attempt is being made to complete within the proposed time an adequate survey of the region allotted to this Observatory, for reasons which need not be elaborated here; but, as the same difficulty will arise at other observatories, it may be well to state here the procedure which has been adopted to obviate it.

(1) A plate is accepted if there are on it three times as many stars as given by Argelander for the same region; or if there are at least 300 stars on it.

(2) In future the third exposure of 20 seconds will be extended to 1 minute.

(3) Before measuring a plate the number of stars showing all three exposures is counted. If there are 300 of these, or "three times Argelander" (which *may* happen even with a 20-second exposure), *these only* are to be measured. If there are not, the number showing two exposures will probably not be excessive.

The following table shows the rate at which the measures are being made. In two periods of ten weeks each, ending on the dates given, there were measured :—

Date.	Star-places.	Plates.	Hours Occupied.	Number per Hour.
1897 March 27	22361	90	573	39
1897 September 25	32989	68	547	60

As regards the accuracy of the measures, it is shown in the paper already quoted (*Monthly Notices*, vol. lvii. p. 621) that the probable error of a resulting coordinate is sensibly less than $\pm 0''{\cdot}20$, the limit assigned by the Conference. An independent

check on the accuracy is afforded by the Cambridge meridian observations. The discordances which appear in the course of the work are nearly always traceable to errors of computation, sometimes clearly to large proper motion, and very seldom* indeed to any error in the recorded measure. All such cases have been satisfactorily explained. One case was outstanding for some time, there being two meridian observations at Cambridge of a star which did not appear on our plates, but it was ultimately identified as the well-known variable *T Andromedæ* !

It is a pleasure for the director to record his appreciation of the admirable way in which Mr. F. A. Bellamy has organised and superintended this important but most laborious piece of work throughout the year.

Temple Observatory, Rugby.

The work of this observatory has been continued as usual. It has been largely of an educational character, and it is hoped that the value of the Observatory in this respect is increasing. During the later portions of the evenings the measurement of double stars has been continued, and it is thought that with the limited means at disposal no better work can be carried on.

Stonyhurst College Observatory.

The meteorological and magnetical continuous records have been carried on as usual, and reports sent to the Meteorological Office and Registrar-General.

The grating of the solar spectrograph was cleaned on Oct. 14, and it is now in a better condition than when first used by the present director in 1890. Fifty-four trials on the H–K region of integrated solar light have been made since the date of cleaning, and these appear to show that only the best photographs can be accepted in evidence against the existence of the double reversals of calcium light. Owing mostly to the unfavourable state of the sky, only half the number of plates exposed since October 14 developed into good photographs. On all of these one at least of the pair of bright lines is plainly seen, generally both ; and always the more refrangible of the two is the stronger. On the same day a good photograph has shown the double reversals, while an inferior one, taken nearly at the same time, has failed. For this reason nearly all the previous plates, exposed to the duller grating surface, have been rejected, as not affording reliable evidence against the existence of the lines.

One hundred and seventy-four drawings of Sun-spots and faculæ have been made to the usual size, and a series of enlarged drawings of spots near the limb was commenced in the middle

* Mr. Bellamy remembers only two such cases occurring among 5000 stars compared.

of September with the hope of obtaining evidence of greater value about the level of the umbra.

Two hundred and forty photographs of stellar spectra have been obtained. The greater number of these are repetitions suggested by a preliminary examination of the plates already in hand.

Twenty-one photographs of the spectrum of *o Ceti* have been obtained during its period of maximum brightness, and a complete map and table of wave-lengths have been prepared for presentation to the Society. The spectra of other stars of the same class are under examination at present, with the object of forming a comparison series.

Dr. Common's Observatory.

During the past year the 5-foot has been mounted as a Cassegrain. The mirror having been refigured very slowly, some trial photographs give very good images of the four stars in the trapezium of *Orion*. Some 12-inch cœlostats have been made and some 30-inch mirrors with holes in centre, and work on plane mirrors has been carried on very successfully.

Mr. Edward Crossley's Observatory, Bermerside, Halifax.

The work of this Observatory during the year 1897 differed in no special respect from that of recent years. The planets *Jupiter*, *Mars*, and *Venus* received most attention, but measures of a few binary stars were also made. The planetary observations have already appeared in the *Monthly Notices* of the Society. The usual meteorological observations were made daily at 9 A.M. and 3 P.M., and monthly reports sent to the Registrar-General; the usual rainfall reports, both summary and detailed, have been sent to Mr. Symons and others.

The new 9-inch triple object-glass by Messrs. T. Cooke & Sons has continued to give perfect satisfaction.

Wolsingham Observatory (Rev. T. E. Espin's).

During the past year sweeping for stars with remarkable spectra has been continued, and 235 stars of types II., III., or IV. have been observed. A catalogue of all the stars observed with the spectroscope since 1886 has been commenced. This has been divided into three parts: the first, containing 848 stars observed 1886–92, the second, containing 1380 stars observed 1892–94, have been completed, while the third, containing the observations 1895–97 has been completed as far as xvi. hour, and contains 858 stars. Observations of various suspected

variable stars have been continued during the year, and the following have been added to the list for confirmation :—

	°	h m	° ′	Variation.	Type.
Es 968*	B.D. + 62·161	0 45·3 (1900)	62 23	8·4 to 9·5	III.
Es 972	+ 45·624	2 27·0	45 13	8 „ 9	III.
Es 867*	+ 26·3486	19 9·1	26 36	8·6 „ 9·8	III.
Es-Birm 649*	+ 41·3632	20 6·3	41 12	8·9 „ 9·5	IV.
Es 911*	Anonymous	20 30·0	54 37	9·3 „ 15	III.
Es 1232	+ 67·1283	21 0·4	67 46	6·8 „ 8	I.

The stars marked * have been so far observed as to leave no real doubt as to their variation. The last star is suspected to have a double spectrum of dark and bright lines, and is the centre of N.G.C. 7023. Some plates have been taken with the 8-inch photo-telescope of several suspected variable stars.

Sir William Huggins' Observatory, Upper Tulse Hill.

The series of photographs of stellar spectra, which include the ultra-violet region of the spectrum as far as reaches us through the Earth's atmosphere mentioned in the last report, has been continued, so far as weather has permitted, during the past year. These photographs are taken with Iceland spar and quartz spectroscopes attached to a Cassegrain reflector, with metallic specula, of 18 inches aperture.

Advantage has been taken of a recent modification of the reflecting slit employed by Sir William Huggins in 1875, which was described in *Astronomy and Astro-physics*, 1893 August, p. 618, to take separately the spectra of closely associated stars.

Early in the past year an automatic mechanical arrangement was devised for giving the necessary breadth to stellar spectra on the photographic plate, which has been found to answer admirably in several respects—namely, by diminishing considerably the irksomeness of constant personal attention; by the saving of time of exposure, since every moment tells upon the plate; and by increased uniformity of photographic action throughout the breadth of the spectrum. This arrangement consists of a toothed wheel, through which the clock motion passes on its way to the driving-screw, which is furnished on one half of its circumference with one tooth more, and on the other half with one tooth fewer than the number of teeth required to transmit the clock-motion without alteration.

With the assistance of these improved arrangements, photographs have been taken separately of the spectra of the two brightest of the small stars forming the trapezium in the nebula of *Orion*. These spectra, confirming others taken during the last two years, show that bright radiations are associated with the

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corresponding dark lines, and in most cases not symmetrically, but more or less to one side. A comparison of the photographs taken from 1894 leaves little doubt that the relative positions of the dark and of the reversed bands are subject to change, suggesting the class of phenomena present in *β Lyræ*, and in *Nova Aurigæ* soon after its first appearance. This investigation is still in progress. The dark lines of the hydrogen series can be traced as far as Hπ. The calcium line K is very thin, and is near a bright radiation which may or may not be associated with it.

The spectra of the contrasted coloured components of double stars have been separately photographed, among others those of the components of *β Cygni*, *α Herculis*, *Cor Caroli*, and *γ Leonis*. The study of these spectra is of great interest in connection with the probable evolution of binary stars, in which case they should be of the same age, and composed of the same substances, though not necessarily in the same proportions. In the case of blue and yellow components, the small blue star shows a type of spectrum more or less after the order of the white stars, which are regarded as evolutionally earlier than the solar type to which the brighter yellow star usually approximates. It may be, however, that the less bright blue star may be of greater mass, and so behind the other in evolutional progress.

It may be stated that in the spectrum of *α Lyræ* sixteen dark lines can be counted beyond H, so bringing the hydrogen series up to H ϕ. The spectrum itself extends on the plate as far as λ 3000.

In the laboratory, experiments on the spectrum of calcium have led to the important fact that density is the determining factor in the modifications of its spectrum as seen in the celestial bodies. The hitherto perplexing behaviour of the H and K lines, often appearing alone, as in the prominences, is shown to be what takes place normally when the density of the calcium vapour is of extreme tenuity, as it must be in the solar prominences. Under these conditions, photographic spectra have been obtained, consisting solely of H and K, the latter line being the stronger of the two, as is the case in prominence-spectra photographed by Hale and by Deslandres. These results furnish us with an experimental criterion by which the relative densities of stellar atmospheres, when suitable lines of calcium are present, may be ascertained.

Other lines of research, both in the observatory and in the laboratory, are also in progress.

Rousdon Observatory, Lyme Regis (Mr. C. E. Peek's).

The building and equipment of the Observatory has been maintained in its usual order. The weather has on the whole been unfavourable, but observations have been made on 156

nights. This is somewhat below the average. The 6·4-inch equatorial has been kept at the regular observation of long-period variable stars on the same lines as during the previous eleven years, and 463 determinations of magnitude have been made. Twenty maxima and 23 minima have been observed. Twenty-five long-period variables are under regular observation; these being mostly circumpolar, the light variations are continuously recorded.

Variable Star Notes No. 2 has been recently published and distributed. This contains the observations of *T Ursæ Majoris* and *S Cephei* for the ten years 1887 to 1896. The results are given concisely in tabular form, accompanied by diagrams of the light curves.

Transits of stars have been taken as often as required for the rating of the sidereal clock.

Dr. Isaac Roberts's Observatory, Crowborough Hill, Sussex.

The work done at this Observatory during the past year will be estimated by the following list of selected photographs which have been taken with the 20-inch reflector, and is given in continuation of similar lists which have been published in the *Monthly Notices*, vol. lvii. pp. 261, 262 and in the volumes for the previous years. The photographs are available for reference, as also are those taken in former years.

A photograph, 15 degrees in diameter, of the sky surrounding each of the objects in the list has been taken with the 5-inch Cooke lens simultaneously with the reflector photograph, and it is hardly necessary to repeat that upon hundreds of the special photographs which have been taken with the 20-inch reflector during the past twelve years there is much matter that is new to astronomers that ought to be preserved in a permanent form for correlation with other photographs which will be taken in future years.

This important subject is now receiving close attention, and it is the more pressing for the reason that the very sensitive photo-films (which are used and are essential to success in recording the very faint nebular and other faint objects in the sky) will not survive the lapse of many years without serious deterioration. The films will cease to show the faint nebulous structures originally visible upon them, and they will gradually become darker in colour, until ultimately the faint stellar images and nebulosity will cease to be visible.

List of the Principal Photographs taken in 1897.

	R.A.	Decl.	Expos.
	h m	° ′	m
Neb. Hɟ IV. 42 Piscium	1 43	+ 5 23	90
Neb. Hɟ I. 105 Ceti	1 48	−14 16	90
Neb. Hɟ IV. 23 Ceti	2 22	− 1 38	90
Neb. Hɟ I. 64 Ceti	2 41	− 8 1	90
Nebulæ in the Pleiades	3 40	+23 46	4^h, 8^h, 9^h2^m, and 10^h
Neb. Hɟ I. 155 Eridani...	3 41	− 4 18	90
Neb. N.G.C. 1499 Persei	3 54	+36 8	90
Neb. Hɟ I. 258 Persei	3 55	+51 1	90
Neb. Hɟ II. 524 Eridani	4 31	− 3 22	58
Neb. Hɟ V. 49 Persei	4 32	+50 14	90
Neb. Hɟ I. 122 Eridani	4 36	− 3 3	59
Neb. Hɟ V. 33 Orionis	5 20	− 2 37	90
Neb. Hɟ V. 34 Orionis	5 31	− 1 16	2^h
Cl. Hɟ VI. 5 Orionis	6 8	+12 50	60
Cl. Hɟ VI. 28 Monocerotis	6 33	+10 59	60
Cl. Hɟ VIII. 31 Monocerotis	6 42	− 3 3	60
Cl. Hɟ VI. 18 Monocerotis	6 51	− 7 3	60
Neb. Hɟ IV. 55 Lyncis	8 5	+46 18	90
Cl. M. 48 Hydræ	8 8	− 1 38	60
Neb. Hɟ I. 242 Ursæ Majoris	8 46	+51 43	90
Neb. Hɟ I. 132 Hydræ	9 16	−11 28	90
Cl. Hɟ VI. 4 Sextantis	9 50	+ 4 46	60
Neb. Hɟ I. 164 Leonis Minoris ...	10 30	+37 52	90
Neb. Hɟ IV. 60 Ursæ Majoris	10 32	+54 3	90
Neb. Hɟ V. 7 Leonis	10 38	+15 26	90 and 2^h 51^m
Neb. Hɟ I. 94 Ursæ Majoris	11 35	+38 7	90
Neb. Hɟ I. 203 & II. 733 Ursæ Majoris	11 49	+44 43	81
Neb. Hɟ I. 174 Comæ	11 58	+32 29	90
Neb. Hɟ IV. 56 Ursæ Majoris... ...	11 58	+44 57	90
Neb. Hɟ I. 225 Ursæ Majoris	12 1	+53 18	90
Neb. Hɟ V. 4 Virginis	12 3	+ 3 27	75
Neb. Hɟ V. 41 Canum Ven.	12 12	+38 23	90
Neb. Hɟ V. 5 Comæ	12 16	+18 58	90
Neb. Hɟ I. 30 Virginis	12 19	+ 7 54	90
Nebæ. M. 87, 89, 90 Virginis	12 28	+13 21	90
Neb. Hɟ I. 43 Virginis	12 34	−11 3	90

	R.A. h m	Decl. ° ′	Expos. m
Nebæ. H I. 14, 15 Virginis	12 38	+ 0 20	90
Neb. H I. 42 Virginis	13 4	− 7 16	90
Neb. H I. 85 Comæ	13 6	+23 29	90
Cl. H VI. 7 Comæ	13 11	+18 14	60
Neb. H I. 98 Boötis	13 37	+36 11	90
Neb. H V. 6 Boötis	13 41	+16 50	90
Neb. H I. 6 Virginis	13 51	+ 5 47	90
"Leonid" meteor swarm	14 12	− 5 26	57
" " "	14 25	− 7 30	2^h 45^m
Neb. H I. 126 Libræ	14 40	+ 2 25	90
Neb. H I. 280 Ursæ Minoris	16 37	+78 25	79
Neb. H IV. 50 Herculis	16 44	+47 44	60
Cl. M. 14 Ophiuchi	17 32	− 3 11	2^h 18^m
Neb. H VI. 41 Draconis	17 33	+75 48	2^h 49^m
Neb. H IV. 37 Draconis	17 59	+66 38	60
Neb. Σ 6 N. Taur. Poniat.	18 7	+ 6 49	60
Cl. M. 16 Clypei	18 13	−13 50	2^h
Hind's var. neb. in Aquila	19 6	+ 0 52	2^h 15^m
Stars in Cygnus	19 45	+35 30	60
Neb. H IV. 72 Cygni	20 8	+38 5	74 and 2^h 51^m
Neb. H IV. 13 Cygni	20 12	+30 15	60
H's Nebulous Region No. 42	20 43	− 1 53	90
" " " " 43	20 53	+16 44	90
" " " " 45	20 57	− 1 34	90
Neb. H IV. 52 Cassiopeiæ	23 16	+60 37	60

Mr. Wilson's Observatory, Daramona, Streete, co. Westmeath.

During the early part of the year some stellar photographs were taken with the 24-inch reflector. The later part of the year has been cloudy and wet.

Early in the year a special form of Cinematograph was ordered for the 4-inch photo-heliograph, in order to try whether it would be possible to show visually the changes in the forms of Sun-spots. Unfortunately the instrument could not be got from the makers until the end of the year, when the Sun was too low to use it. Measures of the radiation of Sun-spots were continued when a spot of sufficient size was visible.

Hong Kong Observatory.

Hourly meteorological observations and continuous records, weather forecasts, storm-warnings, magnetic observations, and the public time-service have been continued as usual. During the summer and autumn the Director attended the British Association meeting in Toronto and the American Association meeting in Detroit, and visited a number of observatories and weather-bureaus in America, especially the Emerson McMillin Observatory, Columbus, Ohio, where he acquainted himself with the latest advances in spectroscopy under Professor H. C. Lord. During his absence Mr. Plummer continued the astronomical observations, and Mr. Figg took charge of the meteorological work. The number of observations of pairs of stars made by Talcott's method is as follows:—1896 October, 135; November, 165; December, 207; 1897 January, 101; February, 61; March, 7; April, 51; May, 134; June, 26; July, 144; August, 152; September, 165; October, 147; November, 230. The number of observations made is limited by atmospheric conditions, and shows the regular annual period which characterises the weather here. With reference to the time-service, the greatest interval of cloudy weather during which no observations were obtained was 16 days in 1897 January and February, after which the error amounted to $0^s.5$. The greatest period previously met with amounted to 23 days in 1887 January and February, after which the error amounted to $0^s.9$.

Melbourne Observatory.

Meridian Observations.—These were made with the 8-inch meridian circle, and are as follows, viz.:—

Observations in R.A. clock stars		687
,, ,, R.A. list stars		999
,, ,, R.A. azimuth stars		230
	Total	1916
Observations in N.P.D. list stars		1003
,, ,, N.P.D. azimuth stars		146
	Total	1149
Observations for level		345
,, ,, collimation		129
,, ,, flexure		13
,, ,, runs		45
,, ,, nadir		102

Reductions.—The separate results and catalogue for 1896 have been completed, and the greater part of the stars observed in 1897 finally reduced. The list stars are, as in previous years, stars selected from the plates of the Astrographic Catalogue, to be used as zero stars in connection with and reduction of those plates.

Time Service.—The time-ball was dropped at the old light-house at Williamstown at 1 P.M. standard time on 304 days, and time signals were supplied every day to all telegraph stations in the colony, to the railways, public departments, and places in town. The time-ball failed to drop on three occasions owing to faults on the line.

Stellar Photography:—

Catalogue plates	...exposed 53	rejected 4
Chart plates (single exposure of one hour) ...	„ 75	„ 13
Plates for Oxford Type regions	„ 9	
„ „ trails	„ 22	
„ „ for adjustment of centre	„ 11	
„ on the region surrounding the South Pole	„ 28	

Exposure for Catalogue plates, 5^m, $2\frac{1}{2}^m$, and 20^s.

„ „ Chart „ 60^m.

The rejected plates were found faulty on account of imperfect setting, broken exposure, or insufficient sensitiveness. Ilford star plates have been used throughout. The Melbourne series of catalogue plates is now complete. The total number of chart plates passed as satisfactory is 172.

Magnetic Work.—The photographic registration of the three magnetic elements has been carried on throughout the year with very few accidental interruptions. Absolute measurements of horizontal force, declination, and dip, were made on 15 occasions.

Meteorological Service.—The number of rainfall stations has increased this year to 552. Two forecasts have been issued daily at 1 P.M. and 6 P.M. Rainfall statistics and meteorological records for all stations in the Colony for the year 1896 were reduced and published, and those for 1897 are being made ready for the press. This work has been generally carried on as in former years.

Rating of chronometers and testing of meteorological and nautical instruments have been continued as usual.

Special Cloud Observations.—These observations have been made throughout the year in connection with the scheme of the International Meteorological Committee. Some 12 observers terminated their work in June last, and 18 have continued it till the end of the year. Some 20,000 observations have been collected of cloud form, direction of motion, and apparent velocity, while the measurements of absolute height and velocity of clouds have been carried on at two stations (one of which is the

Melbourne Observatory), by simultaneous photographs taken with cameras permanently adjusted with their optical axes truly vertical, as mentioned in last year's report. This work has proved very interesting, and a large number of paired pictures have been obtained, several of which have already been measured and have given satisfactory results. The length of the present base is 6820 feet, which is only adapted for the higher clouds, and it is intended to continue the work a few months longer with a shorter base. A detailed description of the method employed in taking the pictures, making the adjustment, measuring and deducing results, will be given in the proper place.

General Remarks.—In October last, Mr. F. N. Ingamells, who had left the Observatory in April 1895 in consequence of a retrenchment scheme put forward by the Government at the time, was reinstated in the position of Clerical and Meteorological Assistant, and since then, by a re-arrangement of routine duties, the Astrographic Observer has been and will in future be enabled to devote the whole of his time to astrographic operations, and it is thus expected that the taking of the chart-plates will now be proceeded with at a more satisfactory rate. The Astrographic Observer had hitherto to discharge several daily duties which necessitated his attendance from 9 A.M. till 5 P.M., and could not therefore be expected to utilize more than 3 hours in the earlier part of the night—namely, before 11 P.M. It is for this reason that the photographic chart has progressed so slowly in the past years.

In every other respect, however, the conditions of the Observatory are the same as reported last year. Consequently it has not been found possible to make systematic observations with the Great Telescope and other equatorials; to publish astronomical results which have been ready for the press for some years; to reduce and prepare for publication the existing material in connection with the Great Telescope and terrestrial magnetism, nor to commence the measurement of the plates of the Astrographic Catalogue. Other important operations, among which is the determination of the division error of the transit circle, and the preparation of a general catalogue, including the meridian observations of the past 13 years, had also to be postponed. These matters were mentioned in the report to the Board of Visitors to the Observatory in August last, and the Government was urged by the Board to provide the necessary assistance to place the Institution in a more efficient condition.

The Director went to Sydney early in January to discuss with the Director of the Observatory of that place, Mr. H. C. Russell, the best means of measuring and reducing the Catalogue plates, and it was agreed and decided that all the plates of both Observatories are to be measured at Melbourne by a Bureau consisting of the Astrographic Observer at this Observatory, and four women, to be specially trained for this work. The expense is to

be shared by the two institutions, and the approval of the respective Governments is awaited, as well as the necessary funds to carry out these intentions. In regard to the meridian circle observations of 10 zero stars for each Catalogue plate, the Adelaide Observatory has continued to assist in these observations, and it is intended to ask the Perth Observatory, when ready, to join in similar work.

The complete Catalogue of such stars will include some 13,000 places or more, of which some 3300 only have been completely observed.

Natal Observatory.

The observations made at the Natal Obse rvatory during the year 1897 have been confined to those necessary for carrying on the ordinary routine work.

The outbreak of rinderpest having cost the colony nearly three quarters of a million of money, the printing of the results of the astronomical work done at the Observatory has been postponed *sine die*. The manuscript of the memoir on the corrections required by the lunar tables to bring them into accord with observations found in the comparison with theory of the whole series of Greenwich observations between 1750 and the present time, is to be done up in brown paper, tied up with red tape, and carefully stowed away on a shelf for an indefinite period, as its length—some 250 pages—would possibly render it too long for the Memoirs of the Society.

The tables founded on the results obtained can be reduced into a form which could be printed without much expense as soon as the necessary time can be found for recasting them.

One of the more interesting facts established is that, owing to an important factor having been overlooked in determining the value of the equation of the centre from the discussion of the observations, all the values hitherto obtained for the eccentricity of the Moon's orbit are incorrect. That deduced by Airy from the discussion of the Greenwich observations for 1750–1851 must be changed from 22639″·06 to 22645″·09. This will necessitate changes in the whole series of numerical values given by Hansen, Delaunay, and others as the theoretical values of the principal inequalities in the motion of the Moon. Thus Delaunay's value for the evection is really 4589·0 instead of 4586·4. Hansen's value for the motion of the lunar perigee also requires material modification.

Perth Observatory, Western Australia.

The astronomical instruments have not yet been received from the makers ; they are, however, now completed, and will shortly be erected. The Government of Western Australia sent the Government Astronomer to England in May last in order to

inspect these prior to shipping them, and he considers that they are in every way satisfactory. A short description is given in the report for last year. With the transit-circle the principal work will be the determination of the exact positions of the 480 stars in the southern heavens selected some years ago by Dr. Auwers. Some attention will also be paid to reflexion observations in view of the possibility of R—D discordances, as it is hoped that, owing to the peculiar construction of the transit room, irregularities of refraction inside the room will be avoided.

Sydney Observatory.

There has been no change in the staff, but Mr. Sellors was absent for four months making computations for another Government Department, in accordance with the rule of the Public Service Board under which a temporary pressure of work in one department may be met by *borrowing* an officer from another, and on this occasion the Observatory had to suffer.

Meridian observations in R.A., clock stars	445
„ „ „ R.A., zone stars	535
„ „ „ N.P.D., clock stars	445
„ „ „ N.P.D., zone stars	535
Determinations of level	392
„ „ collimation	298
„ „ nadir...	392
„ „ azimuth	94

Level and Nadir are observed every morning except Sunday to furnish data on the slow change in the foundations of the instrument.

Equatorial.—Only 50 evenings were available for double star measures. 28 other fine nights had to be devoted to visitors.

The number of Double stars measured	101
Settings for position angle	503
„ „ distance	529

Eighty-three of the double-stars measured are found in the Sydney lists of new pairs for 1882 and 1883.

Astrographic.—Plates taken for Catalogue	1
„ „ „ Chart	385
„ „ „ tests	13

Exposures of over 1 hour are no longer possible in Sydney, because all the city gas lights have been converted into incan

descent burners, and this light, reflected by dust and smoke, fogs the plates.

The effort to remove the Observatory this year has proved unsuccessful, but it is hoped that it may succeed later.

Meteorological.—Weather charts, with forecasts, have been issued every forenoon, Sundays excepted; and since the beginning of August a second chart and forecast has been issued at 9 P.M.; the public reognise this later information as a material improvement.

A system of publishing charts of the colony showing whenever rain falls, the amount, and locality, has been accepted by the public as a great convenience.

General.—One book and eight pamphlets have been published, and of these, in all 3332 copies have been distributed, and in addition 17,500 weather charts, and we have received from other Observatories 1039 books and pamphlets, which have been all duly acknowledged. The number of meteorological observing stations has increased to 1,565.

915 persons have visited the Observatory during the year.

Lovedale, South Africa (Mr. A. W. Roberts's Observatory).

No observations of variable stars were made here during 1897. A visit to England during the year was made the opportunity for the reduction of all the observations from 1891 to 1896. This reduction gave rise to several allied matters (the question of the amount and nature of the error arising from relative position of the stars in the field being one) which require further observation for their full elucidation. The publication of the final results may therefore be delayed for a time.

Mr. Tebbutt's Observatory, The Peninsula, Windsor, New South Wales.

The weather during the year 1897 was pretty favourable for astronomical undertakings. The following is a summary of the work done.

Meridian Department.—The work with the Cooke & Sons 3-inch transit instrument and John Poole 8-day sidereal chronometer comprises the following:—

Nights on which the local time was determined ...	168
Stars observed with a declination not exceeding 40° ...	921
Stars in high declination observed for azimuth ...	244
Separate determinations of level error	508
Separate determinations of collimation error	45
Separate determinations of azimuth error	182

The variations of level of the axis of the transit instrument have been great during the year, and frequent adjustments were necessary. The other errors were not so variable.

Extra-Meridian Department.—With the Grubb 8-inch equatorial refractor the following micrometer comparisons were obtained :—

Object.	Nights of Observation.	No. of Comparisons.
Hebe (6)	4	58
Parthenope (11)	13	125
Niobe (71)	7	122
Procne (194)	14	170
Uranus and 41 Libræ	8	213
Neptune and 114 Tauri	6	120
Comet 1897 I. (Perrine)	21	235

Planet *Niobe* was observed in high south declination, and the work on Comet Perrine was nearly all done in the morning sky. In addition to the above observations, 134 phases of lunar occultations of stars and numerous phenomena of *Jupiter's* satellites (February to July) were recorded, chiefly by means of the 8-inch equatorial. In a few cases the Cooke & Sons $4\frac{1}{2}$-inch equatorial refractor was employed. Lastly, comparisons of the variable star *R Carinæ* were made on twenty-nine nights extending from January 4 to August 31.

The author of this report is indebted to Mr. Joseph Brooks, F.R.A.S., for his predictions of occultations of *Nautical Almanac* stars for the first eight months of the year ; to Professor R. Luther, of Düsseldorf, for MS. ephemerides of small planets ; to Mr. C. J. Merfield, F.R.A.S., for comparisons of the planet observations with the ephemerides ; and to Professor H. Kreutz and Mr. C. D. Perrine for early ephemerides of Comet 1897 I., discovered by the latter.

The meteorological observations were made as usual, but at the close of the year this department, with the exception of observations of rainfall and of extreme monthly temperatures, was discontinued, after being maintained for a period of thirty-five years. Some portions of the observations will be continued by the Government at the Hawkesbury Agricultural College, about four miles west of the observatory.

Notes on some Points connected with the Progress of Astronomy during the Past Year.

Discovery of Minor Planets in 1897.

Seven new planets were discovered during the past year as follows :—

Provisional Designation.	Permanent Number.	Name.	Date of Discovery, 1897.	Discoverer.	Place of Discovery.
DH	426	...	Aug. 25	Charlois	Nice
DJ	427	...	27	,,	,,
DK	428	Monachia	Nov. 18	Villiger	Munich
DL	...	...	23	Charlois	Nice
DM	...	...	Dec. 18	,,	,,
DN	...	...	18	,,	,,
DO	...	...	18	,,	,,

The following planets discovered in December 1896 have received permanent numbers since the date of the last report ; DB 423, DC 425, DF 424. DD and DE do not receive permanent numbers, not having been sufficiently observed.

The planet provisionally named DG, discovered by Charlois on August 25, proves to be identical with (188) *Menippe*, which had been missing since 1878, the year of its discovery.

The following planets have been named : (348) *May*, (350) *Ornamenta*, (354) *Eleonora*, (416) *Vaticana*.

The following planets have been observed at one opposition only : 99, 132, 155, 156, 157, 193, 220, 285, 290, 293, 296, 307, 310, 314, 315, 316, 319, 320, 323, 327, 328, 330, 340, 341, 353, 355, 357, 359, 360, 361, 365, 368, 382, 383, 388, 392, 393, 394, 395, 397, 398, 400, 401, 403, and 404. All the other planets, from 1 to 405 inclusive, have been observed at two or more oppositions.

M. Simonin has investigated the orbit of (108) *Hecuba*, the theory of whose motion is interesting but difficult, on account of its period being so nearly half that of *Jupiter*. (*Annales de l'Observatoire de Nice*, t. vi.)

He finds that log a varies between the limits 0·5061 and 0·5104, n between 608″·7 and 618″·6, ϕ between 3° 30′ and 6° 0′. Although he has neglected powers of e beyond the second, yet he

has been able to represent all the observations during 25 years with no error exceeding 4′.

He points out that it is quite possible for a planet whose eccentricity is subject to large perturbations to remain permanently invisible when the eccentricity is a minimum, but to become visible at perihelion when it is a maximum.

Dr. Backlund contributes two papers on the terms of long period in the longitude of the same planet. (*Bulletin Astronomique*, 1897 September and 1898 January.) He points out two methods by which the coefficients in the expressions for these terms can be greatly reduced, and their convergence correspondingly improved.

A. C. D. C.

The Comets of 1897.

Omitting mention of elliptic comets of short period, whose return could be foretold, only one comet has been discovered during the year. We must go back a considerable time to find so barren a record.

Of the comets mentioned in the last report, but whose history was necessarily incomplete, one, that discovered by Mr. Perrine on December 8, was followed in large telescopes up to the beginning of March of this year. Whether the observations will prove sufficiently numerous and long in continuance to permit the orbit to be determined with the accuracy necessary to decide the question of connection with *Biela* is still doubtful. The other, that discovered by the same astronomer on November 2, was observed in the southern hemisphere till the following April; but though the comet came again above our horizon in the summer, it appears to have been too faint and too near the Sun to have been re-observed.

D'Arrest's Comet, for which M. Leveau provided an ephemeris, was discovered at the Lick Observatory by Mr. Perrine on June 28. He speaks of it as being visible in a 3¼-inch finder, but owing to its proximity to the Sun and the long twilights of that time of the year it does not appear to have been generally observed in Europe. The error of the ephemeris was about four minutes of time in right ascension and rather more than four minutes in declination, which could be approximately removed by reducing the mean anomaly twenty minutes. A sufficient number of observations have been made to secure improved elements.

On October 16, Mr. Perrine discovered a telescopic comet in *Camelopardalus*, moving rapidly towards the pole. Owing to the moderate brightness of the comet and its favourable position in the sky, it was very generally observed, and numerous measures have been collected. In ordinary telescopes the appearance of the comet was not very striking, but in the 36-inch of the Lick Observatory a well-defined nucleus was clearly seen, and at the time of discovery, when the comet was near to its maximum

brilliancy, a tail could be traced for some three or four minutes. A photograph taken by Professor Hussey showed a tail extending ten minutes from the nucleus with sufficient clearness to permit the measurement of the position angle. The comet faded more rapidly than the formula expressing the theoretical brilliancy intimated, and by the middle of November it had practically disappeared. The orbit is likely to prove parabolic.

Although Winnecke's Comet was first seen in the current year, it seems desirable to mention its discovery in this place. Again we are indebted to the careful scrutiny of Mr. Perrine for this fortunate recovery, who shortly before sunrise on January 2 picked it up, guided by the ephemeris of Dr. Hillebrand, by whom the calculations have been undertaken since the lamented death of Professor v. Haertdl, whose researches on the motion of this comet are well known. The ephemeris, rapidly prepared to prevent any delay in rediscovery, proved to be about two minutes of R.A. and nine minutes of δ in error. The theoretical brilliancy at the time of discovery was less than when found in 1892, suggesting an increase in intrinsic brightness, but the light of the morning sky will probably prove more effective in preventing observations than any actual faintness of the object.

Though two of the family of short-period comets have been recovered on their return to the Sun, two have unfortunately escaped. Spitaler's Comet of 1890, which probably passed its perihelion in March, has not been seen. The chances for seeing it, never very great, were best towards the end of 1896. The comet of Tempel-Swift has also been in perihelion early in June, but, notwithstanding the careful discussion of the perturbations by M. Bossert, of the Paris Observatory, and the construction of a more than adequate ephemeris to assist the recovery, it has not been seen, owing to the faintness due to its great distance from the Earth.

Among the more interesting contributions to cometary literature should be mentioned Dr. Holetschek's investigation of the magnitude and brilliancy of comets and comet tails, from the earlier times till 1760. The object which Dr. Holetschek proposed to himself in this inquiry was to arrange in order of magnitude those comets whose orbits have been computed, in much the same way that stars are classified by their brilliancy. In addition, an attempt has been made to derive the true length of the tail from the records of apparent length, and to examine to what extent the power of tail construction and the consequent apparent length may be concluded from a knowledge of the magnitude of the comet and its perihelion distance.

The data for determining the magnitude of a comet are necessarily vague and untrustworthy. Dr. Holetschek has had to rely on the record of a date when a comet first becomes visible, or when last seen, as furnishing a definite magnitude, but here such circumstances as twilight, moonlight, approach to horizon, &c., leave a doubt as great, perhaps, as when a comet is compared in

lustre with a planet or a first magnitude star. But from the experience gained in examining many original accounts of comet apparitions, Dr. Holetschek has learnt to translate the description with a fair amount of accuracy, and in many cases, when the comet's brilliancy has been reduced to that of unit of distance ($r=1$; $\Delta=1$) by the application of the ordinary formula $\frac{1}{r^2\Delta^2}$, the resulting magnitudes, derived from various sources, agree fairly satisfactorily. In long extended series of observations, the magnitudes for distance unity have a tendency to exhibit a regular progression, suggesting the inappropriateness of the general formula. Dr. Holetschek finds that Δ^2 is a justifiable factor, but the employment of the square of the radius vector is not so well founded. In modern instances, Encke's and Winnecke's comets both require a much higher exponent, but the value deduced, though it secures better arithmetical results, has no real physical signification.

Of the many historical accounts examined, some 70 lend themselves to a fairly satisfactory determination of magnitude at distance unity, and about 50 permit a numerical value to be assigned to the length of the tail. The magnitudes range from -1 (the great comet of 1744) to $9\frac{1}{2}$, but the greater number fall between the magnitudes $(4-6)$. The length of the comet's tail is necessarily an uncertain quantity, and it would not be safe to conclude more than that the tail is greater, the greater the magnitude, and the closer the approach to the Sun. When the magnitude of the comet for $r=1$, $\Delta=1$ is about the sixth, or less than the sixth, as a rule no tail is developed that can be seen with the naked eye, or only under the most advantageous circumstances, as when the comet comes near the Earth. With magnitude four, almost all comets when near perihelion have a tail visible without optical aid, but when the perihelion distance is large, as in the case of the comets of 1729 and 1747, the tail development is very slight.

Halley's Comet has been made the subject of a special examination, with the result that the magnitude at each return, when reduced to unit of distance, has remained fairly constant. For a thousand years, 837 to 1835, this magnitude has been between the third and fourth, while the length of the tail from 1456 to 1835 shows no great variation. Dr. Holetschek concludes from these figures that, notwithstanding the reasons which would suggest that at each return the comet must part with some of its materials, this loss is so small that it remains within the limits of uncertainty in deriving the magnitude of the comet.

W. E. P.

Progress of Meteoric Astronomy in 1897.

Photograph of the Spectrum of a Meteor.—Professor E. C. Pickering writes to *Ast. Nach.* 3461, that on 1897 June 18, when the 8-inch Bache telescope at Arequipa was directed towards the constellation *Telescopium* for the purpose of obtaining photographs of the spectra of stars, a bright meteor appeared in R.A. $18^h\ 19^m$, Decl. $-47°\ 10'$, and passed out of the field at R.A. $18^h\ 29^m$, Decl. $-50°\ 30'$. "The spectrum consists of six bright lines, whose intensity varies in different portions of the photograph, thereby showing that the light of the meteor changed as its image passed across the plate. The approximate wave-lengths of these lines are 3954, 4121, 4195, 4344, 4636, and 4857; and their intensities are estimated as 40, 100, 2, 13, 10, and 10 respectively. The first, second, fourth, and sixth of these lines are probably identical with the hydrogen lines Hϵ, Hδ, Hγ, and Hβ, whose wave-lengths are 3970, 4101, 4341, and 4862. The fifth line is probably identical with the band at wave-length 4633 present in spectra of stars of the fifth type, and forming the distinctive feature of the third class of these stars. The third line, which is barely visible, is perhaps identical with the band at wave-length 4200 contained in these stars."

An Enormous Block of Meteoric Iron.—Eighty years ago, when Sir John Ross discovered the Eskimos of the Cape York region, he found that the metallic knife blades, harpoon heads, and other instruments in use amongst them were formed of meteoric iron, said to have been derived from iron mountains in Melville Bay. Lieutenant Peary, travelling in this region in 1894, found one huge block and two smaller masses of meteoric iron, weighing respectively 200,000 lbs. (90 tons), 6000 lbs., and 1000 lbs., which the Eskimos had utilised for many years in making cutlery. In 1895 Lieutenant Peary brought the two minor ones back to America, and in the summer of 1897 he transported the large mass in the steamer *Hope* safely to New York. It measures 12 ft. by 8 ft. by 6 ft., and a sample of this enormous block, in the possession of its finder, looks like highly polished steel, and the beautiful Widmanstätten figures, forming the usual feature of meteoric irons, are finely marked upon it. An analysis has proved it to consist of 92 per cent. of iron and 8 per cent. nickel.

Perturbations of Meteoric Streams.—Professor Theodor Bredikhine, in the *Bulletin* of the St. Petersburg Academy, vol. v., November 5, gives the results, quoted in *Nature*, November 25, of his investigation as to what members of the solar system are responsible for disturbances in those meteoric systems encountered by the Earth in her annual orbit. He finds the Sun's effect is predominant in the great majority of cases, and especially so when the perihelion distance is small. In several instances,

however, there is a near approach to one or other of the major planets. Professor Bredikhine's previous inquiries as to the nature and motion of the tails of comets have indicated that the force of projection at the period of outburst is sufficient to change the paths of numbers of the constituent atoms from parabolic to elliptic orbits of short period. He adopts the view that meteoric systems generally are composed of the fragments of comets which, in traversing interplanetary space, lost a portion of their material by disturbing influences exerted by members of the solar system. The larger proportion of the meteoric streams examined by Professor Bredikhine have resulted from large disturbances at the nucleus caused by the Sun, and amongst these are the *Leonids*, *Quadrantids*, *Geminids*, and *Aquarids*. The *Orionids* owe their presence to the perturbations set up by *Jupiter*, while the *Lyrids* are due to *Saturn*.

Height of a Meteor found by Photography.—At the Lick Observatory, on 1896 November 13, $13^h\ 30^m$ to $17^h\ 8^m$ P.S.T., a meteor trail was photographed simultaneously on plates exposed in two cameras 1384 feet apart. Two different lenses were, however, employed, and the inaccurate focus of one of them, combined with the short base line, made it impossible to get very precise results as to the real path. Messrs. Schaeberle and Colton therefore determined to compute the height of the middle point of the path. The parallax was found to be $9''{\cdot}06$, and the distance above the surface of the Earth 99 miles.

January Meteors.—Mr. H. Corder, at Bridgwater, watched the sky on the night of January 1, and in about 6 hours of clear sky saw 109 *Quadrantids* and 21 other meteors. Mr. T. W. Backhouse, at Sunderland, saw 97 meteors on January 1, and of these about 86 were *Quadrantids*.

August Meteors.—Near the time of maximum moonlight was too strong for the shower to present any brilliant features. Professor A. S. Herschel, at Slough, made an extensive series of observations from July 20 to August 9, and during watches, amounting in the aggregate to $33\frac{1}{2}$ hours, observed 280 meteors, of which 114 belonged to the great *Perseid* stream. As early as July 22 the shower formed a distinctly recognisable display from the point $23°+49°$, and on later nights took up positions to the E.N.E., in conformity with the usual displacement it exhibits.

In *Ast. Nach.* 3463 appears a summary of 78 radiants of the *Perseids* derived from a number of miscellaneous observations during the last five years. The comparison of these results exhibits the shifting of the centre very well, though there are irregularities obviously occasioned by the errors of observation.

November Meteors (*Leonids*).—M. Lucien Libert, at Le Havre, France, watched the sky on November 13 from 12^h to 18^h, and registered 51 meteors, including about 21 *Leonids*. The writer reprojected these observations, and found the radiant diffuse to the extent of 8°, with a centre at R.A. 150° Decl. +24°. Mr. W. E. Besley, of Westminster, maintained a look-out after midnight

on November 13 for $5^h\,20^m$, and saw 27 meteors, of which 20 appear to have been *Leonids* from a radiant at R.A. 149° Decl. +23°. Professor E. C. Pickering, at Harvard, on November 13, reports that his observers saw only 90 meteors during the night, butthat these were nearly all *Leonids*.

On November 14 clouds appear to have veiled the sky nearly everywhere, and few accounts have come to hand. Professor Lewis Swift, writing from Lowe Observatory, Echo Mountain, Cal., says : "The *Leonids* made their appearance on the morning of November 15, as predicted, 97 having been seen by one person."

Mr. Robert Service, an amateur observer of Dumfries, writes that on November 14 the weather cleared up shortly after midnight, and the sky was free from clouds until daylight. Between $12^h\,30^m$ and $16^h\,15^m$ he saw 33 meteors (17 *Leonids*), and then went indoors, though the *Leonids* were increasing, more than half the whole number seen during the night being observed from $15^h\,42^m$ to $16^h\,9^m$. He was afterwards informed by two persons that, when proceeding to their work at about 5 A.M., November 15, their attention was attracted by numbers of shooting stars.

The shower of *Leonids* was fairly active on the morning of the 16th, for Herr Nyland, of Utrecht, observed more than 40 meteors, chiefly *Leonids* ; and of these 10 were brilliant, several of them being comparable with *Venus*.

November Meteors (*Andromedids*).—Mr. P. M. Ryves, of Stone, Staffs., watched the sky on November 27, between $7^h\,40^m$ and $9^h\,44^m$, and counted 20 meteors, of which apparently 6 or 7 were *Andromedids*. The radiant point was near γ *Andromedæ*, but was not well defined.

Fireballs.—A considerable number of large meteors appeared during the past year, but very few of them were observed accurately at two or more stations. On April 30 at $9^h\,37^m$ a fireball estimated $5\times\,♀$ was seen by the writer at Bristol. The observed part of its path was from R.A. 166° Decl. +51° to R.A. $154\frac{1}{2}$° Decl. +31°. It was seen at Stroud, Lyme Regis, and several other places, where its sudden and astonishing brilliancy startled the observers. At Lyme Regis it was estimated as half the diameter of the Moon. It descended from a height of 59 miles above Cheltenham to 18 miles above Banwell, Somerset, and traversed a real path of 70 miles at a velocity of 23 miles per second. Its Earth point was 4 miles N.W. of Taunton, and from this place it must have appeared as a brilliant stationary object in its radiant point at 291°+59°.

On July 30 at $8^h\,47^m$, in strong twilight a magnificent meteor was seen at Bridgwater, Southampton, Tunbridge Wells, Upton near Slough, Henley-on-Thames, Collumpton (Devon), Lyme Regis, and other places. It fell from a height of 54 miles over Poole, Hants, to 23 miles over the English Channel, after a flight of about 50 miles, and velocity of 13 miles per second. The observations are not quite accordant, and the radiant point is

not indicated with certainty ; but it was near *β Ursæ Majoris*, and at about R.A. 155° Decl. +59°.

On August 2 $13^h\ 57\frac{1}{2}^m$ a fireball 3 × ♀ was observed by Professor A. S. Herschel, at Slough, and Mr. H. Corder, at Bridgwater. It fell from a height of 81 miles over a point 10 miles E. of Tavistock, Devon, to 47 miles over Watchet, Somerset, after a visible course of 59 miles. It was directed from a radiant point on the equator at R.A. 312° Decl. ±0° in *Aquarius*.

On August 8 $9^h\ 15^m$ a fireball excelling ♀ was seen by Professor Herschel at Slough, and by Mr. N. Lattey at Cardiff. The meteor appears to have been a *Perseid*, but the heights are unusual—viz. from 133 to 115 miles over Hampshire and the English Channel. The real path was about 63 miles ; velocity about 42 miles per second.

On August 9 $14^h\ 18^m$ another brilliant fireball 3 × ♀ was seen by Professor Herschel, and the same object appears to have been recorded by Mr. W. E. Besley at Exeter, but there is a doubt as to the magnitude, though the path conforms well. Again the resulting heights are excessive, for the meteor descended from 137 to 75 miles along a course extending over 75 miles.

These are not the only instances where the computed heights of doubly observed meteors at the August epoch were found to be over 100 miles. Yet it is very unusual to meet with a single case where even the elevation at commencement exceeds that distance. In the following table particulars are given as to the abnormal figures recently found :—

Date. 1897	G.M.T. h m	Mags.	Height at Beginning.	Height at Ending.	Length.	Radiant R.A. Decl. ° °
Aug. 2	11 5½	2	112	90	40	40 + 55
2	11 24	5-4	139	124	28	73 + 66
8	9 15	> ♀	133	115	63	52 + 47
9	13 27	3-1	140	77	81	46 + 56
9	13 52	3	131	89	56	58 + 60
9	14 18	3 × ♀	137	75	75	44 + 45

The mean heights of these six objects are :—

At beginning=132 miles. End=95 miles.

Yet the mean values from six other meteors observed at the same period are only :—

At beginning=63 miles. End=49 miles.

In the autumn many fireballs were observed, but rarely with sufficient fulness or accuracy to enable their real paths to be determined. The dates of their appearance were October 19, 22 ; November 15, 19, 28, 29 ; December 3, 9, 12. The meteors of

December 9 and 12 were splendid objects, and attracted widespread notice. The former of these was a *Geminid* with radiant at about R.A. 113° Decl. +32°, and it fell from a height of 76 to 21 miles over Suffolk and Herts. The latter was a *ζ Taurid* from a radiant at R.A. 80° Decl. +23°, and it fell from 112 to 19 miles over the North Sea and Yorkshire.

W. F. D.

Sun-Spots and Faculæ During 1897.

The year 1897 opened with a slight increase of solar activity, as compared with the last quarter of 1896, and a magnificent spot group was seen crossing the Sun's disc from January 3 to 15. The group occasionally exceeded in area 2500 millionths of the visible hemisphere, and the principal spot approached 2000 millionths. No other group approached this one in magnitude, but the nearest were those seen early in February, May, August, and in the middle of December. Of all these groups the last was the only one north of the equator, so that judging from the larger groups above, the predominance clearly remains, as in 1896, with the southern hemisphere.

More remarkable than the spot groups of the year was the minimum that occurred in the last half of May and the first half of June. For a whole week, May 13–19, the Sun was free from spots, it was again free on June 7, 8, 10, 11, 12, 17, 19; while the mean daily spotted area for the six weeks beginning on May 11, was under 200 millionths.

The results for the end of the year are at present far from complete. On three other days at least, besides the fourteen above mentioned, the Sun was free from spots on March 21, April 23, 24; the Sun was free from faculæ on March 14, May 21, June 1, July 5, August 22, and September 6.

The mean spotted area for 1897 is as nearly as possible the same as that for 1896, the difference probably not exceeding 10 millionths of the visible hemisphere in the daily average.

P. H. C.

Poincaré's Mécanique Céleste.

New and important fields of research have been opened up to dynamical astronomers during the last twenty years. The impetus was originally given by Dr. Hill's papers on the Lunar Theory. Since then, Continental mathematicians have applied to the Problem of Three Bodies the varied resources of modern analysis. M. Poincaré, himself the most distinguished of living workers in this field, has collected the results of recent research in the three volumes of his *Méthodes nouvelles de la Mécanique*

céleste—a work of which we are glad to notice the approaching completion.

The first volume appeared in 1892. After two preliminary chapters—one on the general differential equations of dynamics, and one on integration by infinite series—the author commences in the third chapter the study of periodic solutions. Among the solutions of the general Problem of Three Bodies, there are some in which the relative movement repeats itself at regular intervals of time. A class of these "periodic solutions," as they are called, was discovered by Dr. Hill in his "Researches in the Lunar Theory," published in the first volume of the *American Journal of Mathematics*. Much of the theory in its present form is due to M. Poincaré himself. It was developed in a memoir on the Problem of Three Bodies, which gained the King of Sweden's prize in 1889, and it is the main theme of the present volume.

The problem attacked may be thus stated: In the Problem of Three Bodies, let two of the bodies have their masses zero. Then a class of periodic solutions of the system is known: namely, the motions in which these bodies describe circular orbits about the third body. Is there a corresponding class of periodic solutions when the two masses are small, but no longer zero? Existence theorems are given for such motions, and periodic solutions are arranged in three classes. It is shown that in the second and third of these classes the arbitrary constants of the motion must be such that no secular terms occur.

Much of the remainder of the volume is occupied with the theory of motions which differ only slightly from periodic solutions. Periodic solutions may at first seem to be of no practical interest. It is clearly unlikely that the initial circumstances of the motion will be such as to give rise to an exactly periodic motion. But it may very well happen that they differ only slightly from such values; the periodic solution can then be treated as a first approximation, or "intermediary orbit," just as Kepler's ellipse is in the older theories, and we can regard the actual motion as a disturbed form of it. Dr. Hill has developed the Lunar Theory in this way. M. Poincaré arrives at a general theory of "asymptotic solutions" and their "characteristic exponents." If the characteristic exponents are purely imaginary, the periodic solution is a stable form of motion. The case of the problem of three bodies is discussed at some length, and it is shown that the periodic solutions then have two, but not more than two, of their characteristic exponents zero.

An important chapter is devoted to the integrals of the equations of motion. Herr Bruns has proved (*Acta Mathematica*, xi.) that the Problem of Three Bodies, and, more generally, of n bodies, admits of no algebraic integral other than those already known. M. Poincaré now further develops this theorem by proving that for small values of one of the masses there is no uniform transcendental integral. Dr. Hill, however, considers the proof of this open to criticism.

The sixth chapter deals with the development of the disturb-

ing function, particularly in respect of the long-period inequalities. In seeking to complete his theorem on the non-existence of uniform integrals, the author has discovered an extension of Darboux's work on terms of high order in expansions.

The second volume, published in 1893, treats of the methods of Gyldén, Newcomb, Lindstedt, and Bohlin.

In the ordinary developments of the Planetary Theory the coordinates of the planets are expressed in terms of the time, as infinite series; by taking a sufficient number of terms of the series, it is theoretically possible to calculate the place of the planet with any desired accuracy. But these series have one great defect—they contain terms which increase indefinitely with the time. The efforts of mathematicians have lately been successful in obtaining series free from these "secular terms," as they are called. The developments thus obtained, however, are not convergent in the ordinary sense of the word; having in this respect some analogies with the well-known "semi-convergent" expansions for Bessel Functions. This, as M. Poincaré remarks, does not affect their use for purposes of calculation, but renders them useless for researches into the stability of the system.

Some of the reasoning on the convergency of the developments has, however, been criticised by Dr. Hill; there is room for further research in this connection.

Although the results obtained in the second volume are largely due to other workers, M. Poincaré has introduced considerable modifications in his account of their theories.

The third volume, of which the first part has lately appeared, includes the rest of the work originally given in the memoir "Sur le Problème des trois Corps," already mentioned. The theory of Integral Invariants, which was first developed there, is of importance in questions relating to stability. We can regard a system of ordinary differential equations as defining the motion of a point in space of n dimensions. If now we consider a group of points P, which occupy a ν-dimensional region ζ_0 at the beginning of the motion, they will at any time t occupy a region ζ. A ν-ple integral taken over ζ is called an "integral invariant" if it is independent of t. Thus, in the motion of an incompressible fluid, the volume of fluid contained in any given region is an integral invariant.

The importance of Integral Invariants arises from the following property. Suppose that the volume is an integral invariant, and that the representative point P always remains at a finite distance from its initial position. Then if we take any region of space, however small, there are always an infinite number of trajectories of P which traverse it infinitely often. This theory is applied to extend the discoveries on stability already made by Hill and Bohlin.

This work will be a noble monument of the dynamical astronomers of this generation, and its completion will be awaited with interest. E. T. W.

Professor G. H. Darwin's Researches on Periodic Orbits.

The problem of three bodies in its utmost generality is one far beyond the capacity of analysis in its present state to solve, and all that can be done is to consider a simple case and then the approximations to such simple cases.

It was usual to take as the simple case the problem of two bodies, and as the approximation, the case where the influence of one attracting body predominates largely over that of the other. The problem of two bodies leads to motion in a conic section, in general an ellipse ; and in the cases of the problem of three bodies that occur in nature, the motion is for a time approximately motion in an ellipse. The drawback to this method of treatment is that the disturbing body, however small or distant, causes the apse and node of the ellipse to rotate, and the motion cannot for long approximate to motion in a fixed ellipse. It has been attempted to meet the difficulty by comparing the actual motion with motion in an ellipse whose apse and node revolve : but such a motion has no physical interpretation.

Since, therefore, part of the effect of the disturbing body is secular, and accumulates indefinitely, so that the approximation made in neglecting it loses its accuracy, it was found desirable to attack the problem from a different point of view, in which the influence of the disturbing body should be considered even in the simple case used as the starting point, and where the departures from the "intermediate" orbit should be wholly periodic and not secular.

In 1876 Dr. Hill pointed out that the proper intermediate orbit is that which results from neglecting the eccentricity and inclination, and consequently the evection, and also neglecting the eccentricity of the Sun's orbit. The variation and parallactic inequality are alone left, and the orbit, referred to a plane rotating uniformly with the Sun and upon which plane therefore the positions of the Earth and Sun are fixed points, is periodic, the period being a synodic month. The elliptic and inclinational inequalities, together with the evection, are free oscillations about this periodic orbit ; the annual equation is a forced oscillation. As in other dynamical problems, the period of the forced oscillations is the period of the disturbance, an anomalistic year ; the period of the two free oscillations result from the corresponding period equations, which Dr. Hill has obtained in the form of infinite determinants. Provided only that the periodic orbit is stable and the departure from it small, any required degree of accuracy may be obtained by expanding in powers and products of quantities representing the eccentricity of the Sun's orbit and the amplitudes of the two free oscillations.

The subject of periodic orbits thus opened by Dr. Hill has been pursued, by M. Poincaré and others, from the pure mathematical point of view. M. Poincaré has discussed general questions, such as the cases in which the existence of periodic orbits

may be inferred, their method of appearance and disappearance, as the circumstances are varied, and general laws concerning the periods of oscillations about them.

Professor Darwin has approached the subject from the numerical point of view. His object has been to draw as many orbits as possible, and to trace the changes of form corresponding to changes in the relative energy. He has been the first to extend numerical researches into those regions where the influence of one body no longer predominates over the influence of the other.

To magnify the disturbances, from the scale on which they occur in nature, Professor Darwin has assumed that the smaller attracting body, which he calls Jove, has a mass equal to one-tenth of the mass of the Sun. The relative orbit of Jove and the Sun is circular, the mass of the third body is negligible, so that referred to moving axes both Jove and the Sun can be represented in the diagrams as fixed points.

Taking some definite value for the constant of relative energy, Professor Darwin traces out, by mechanical quadrature, a number of orbits starting at right angles from the line of syzygies. The calculations are continued until the line of syzygies is again reached : if two orbits return to the line of syzygies at an obtuse and acute angle respectively, by interpolation an intermediate orbit can be obtained returning at right angles ; the continuation of such an orbit is the reflection of the part already obtained in the line of syzygies ; it is therefore re-entrant and periodic. In this way a large number of periodic orbits have been obtained, several for each different value of the constant of energy. A comparison of the results shows that the orbits fall into families, each family taking account of the modification of a different orbit, as the constant of energy varies.

Professor Darwin has also considered the question of stability. His methods are analogous to Dr. Hill's. When a series is required, it is obtained, when possible, by the method of special values. The method fails in the case of orbits of fantastical shape, but these may be, with confidence, classed as unstable.

Considerable information is obtained by considering the form of the curve of no velocity. For cases such as occur in nature, the form of this curve shows that the third body must remain a satellite, an inferior planet or superior planet, without changing its rôle. Professor Darwin has considered cases where the third body may pass from Jove to the Sun. Some of his orbits are cusped, the cusp lying on the curve of no velocity ; later members of the same family are looped. In this case the manner of introduction of the loop is easy to follow out. Other orbits, however, pass from simple ovals into figures of eight ; the manner of transition is at present obscure.

In his present paper Professor Darwin has only covered a small fraction of the ground that he has opened up. Now that the methods have been carefully devised, it should be com-

paratively easy for others to follow up Professor Darwin's work, and it is to be hoped that before long information on the subject will be extended.

P. H. C.

Dr. Gill's Determination of the Solar Parallax.

Volumes vi. and vii. of the *Annals of the Cape Observatory*, which have been recently published, are devoted to a determination of the Solar Parallax from heliometer observations of the minor planets, *Victoria*, *Iris* and *Sappho*. Previous experience had convinced Dr. Gill that the Solar Parallax might be determined in this way with great accuracy, and he secured the co-operation of the observatories at Yale, Leipzig, Göttingen, Bamberg, and Oxford (Radcliffe) in a carefully planned and extensive series of heliometric measures of the distances of these planets from neighbouring stars during their oppositions in the years 1888 and 1889. The principle of the method consists in the measurement of a planet's distance from two comparison stars situated as nearly as possible in the same azimuth and at nearly equal distances above and below. Its position is thus determined with great accuracy as the *difference* of two nearly equal distances. A zenith distance of about 60° is most suitable, as giving a large parallax factor and avoiding the uncertainties arising at low altitudes from bad definition and irregular refraction. The personal errors of measurement and the errors of scale will be eliminated if the comparison stars are nearly equidistant from the planet; the errors of the stars' positions will be eliminated if the same stars are used at the northern and the southern observatories; and the errors of the ephemeris will be eliminated if the northern and southern observations are simultaneous. It is not practicable nor even possible to satisfy all these conditions, but an important feature of this method is its "self-correcting" nature—"the observations themselves furnish the material for the determination and elimination of the errors to which it is liable."

The heliometer in use at the Cape, to which the others are in general similar, was made by Repsold, and is of 7 inches aperture and about 8 feet 6 inches focal length. A description of it, with drawings, is given at the beginning of vol. vii. The magnification used was 250 times; a reversing prism eye-piece was employed throughout. The object-glass scales are of irido-platinum and are divided to every $\frac{1}{2}$ mm., the divisions being figured 0 to 200 and 200 to 400 on the two scales. The divisions are very sharp and a magnifying power of 100 diameters is used in the reading microscope; the wires of this microscope are $1''{\cdot}4$ apart, and the divisions can be clearly seen between them. The probable error of a pointing is given by Dr. Gill as $\pm 0''{\cdot}02$. Divisions of the two scales are seen together: a division of one is bisected by the fixed wires of the micrometer and a division of the other by the

moveable ones. The readings are printed on a ribbon of paper, thus saving the observer the necessity of reading them, and preserving a permanent record available for the detection of errors.

The division errors of the scales were determined by comparing each of the 10 division spaces from 10 to 190 of the one scale with each of those from 210 to 390 of the other, the divisions of each scale being simultaneously under the same micrometer. In this way cumulative error in the determination is avoided. A similar method was afterwards applied to the single divisions. The determination of these division errors involved 50,000 pointings, and occupied two hours a day for nine months. The probable error of the value for each principal division is $\pm 0''{\cdot}0048$, and for the other divisions $\pm 0''{\cdot}0092$.

In the different series of observations a large number of measures of position angles have been made in addition to those of distance. Dr. Gill, however, finds that measures of distance can be made with much greater accuracy than measures of angle. The position angles are corrected in the usual way for errors of adjustment of the equatorial. In measuring distances no adjustment of focus is permissible during a set of observations, as this affects the scale, which is determined each night from measures of distances between two standard stars. Dr. Gill finds that the measures of distance require a correction of the form $s\ \Delta\ \sigma + \frac{1}{s} N$. The first term is the scale correction; the second is a personal correction depending on the observer's method of making the star images pass through one another in his estimations of coincidence. It appears that with modern heliometers in which the field is illuminated the sign of this correction is always positive, whereas in the older instruments, without illumination of the field, it was negative. The cause of this correction is considered in detail by Dr. Gill. Any uncertainty in the determination of these coefficients is almost entirely eliminated in the results obtained from nearly equal double distances.

For the meridian observations of the comparison stars for the three planets Dr. Gill secured the co-operation of 22 different observatories. Altogether 9620 observations of 115 stars were secured, and their discussion was undertaken by Dr. Auwers, and is given in vol. vii. Generally speaking, a somewhat preponderating weight is given to one or two observatories, particularly in the case of *Sappho*, where a weight of 410 is given to 404 observations of right ascension made at Berlin, while a weight of 555 is given to 2614 observations made at 14 other observatories. The probable error of the results (considered as relative positions) is given as about $\pm^{s}{\cdot}005$ or $\pm^{s}{\cdot}006$ in R.A., and $\pm''{\cdot}07$ or $\pm''{\cdot}08$ in Decl. The proper motions of all the stars, though in many cases very small, are determined with great care by comparison with all previous observations which can be found. Systematic corrections are applied to the catalogues used in order to

bring them into harmony with A.G.C. system, except in the case of the declinations of the *Victoria* and *Sappho* stars which are reduced to Auwers' system of fundamental stars for the southern zone of the Astronomische Gesellschaft, and which is in close agreement with his previously determined "Mean System." In the discussion of the right ascensions, corrections for variation of personal equation with magnitude are applied to bring the different observatories into harmony with Berlin, and a short account is given of the experiments made with gauze screens to determine the absolute value of this correction. In all the series in which transits were recorded on the chronograph the right ascensions increase with diminishing brightness, but the amount of this increase appears to be only roughly determinable. Dr. Auwers remarks that the same tendency is observable with the "eye and ear" observations.

A triangulation of the forty-two stars used in the *Victoria* series was made from 1867 measures of distance and 151 of position angle, to strengthen the results of the meridian observations. The measures of distance were corrected for refraction, aberration, and scale, the last-named being determined each night by measures of the distance of the standard stars. The resulting distances were further corrected as follows: each observer's measure was compared with Dr. Gill's, and a linear correction was first obtained and applied to the distances to correct for any personality relative to Gill which he may have in making the measures of the brighter standard stars as compared with the ordinary comparison stars: the distances were now compared with the distances computed from the meridian observations, terms being inserted in the equations for magnitude corrections to the right ascensions. The solution of these equations gives the systematic corrections required by Gill for different distances and the coefficients of the magnitude corrections to be applied to the meridian right ascensions. Combining this with the previous comparison with Gill, the systematic corrections required by all the measurers are determined. These corrections are applied to the distances obtained by the several observers, which are next combined with their appropriate weights. By comparison with the distances determined from the meridian observations equations are now formed for every measured pair of stars to give corrections to the assumed right ascensions and declinations. These equations are easily solved for each star by successive approximations. As the result of the triangulation, Dr. Gill reduces the probable error of the right ascensions and declinations to about $\pm''.03$. In this investigation Dr. Gill arrives at the personal correction of heliometer measures of distance, varying inversely as the distance referred to above, but as the numerical values of the correction had been already found, he did not resolve his equations on this assumption.

The observations of *Victoria* were made from 1889 June 10, to August 26. Altogether 1627 observations of distance

and position angle were made. The observations of *Sappho* extended from 1889 September 18 to October 27. In the discussion only measures of double distances are used. *Iris* was observed from 1888 October 10 to November 17, and 1107 measures were made. The observations of *Victoria* and *Sappho* are discussed by Dr. Gill, those of *Iris* by Dr. Elkin. Equations are formed by comparing the measured distances with those computed from an ephemeris. The solution of these equations gives corrections to the ephemeris and a correction to the adopted parallax. In the cases of *Sappho* and *Iris* the corrections to the ephemeris must be regarded as more or less empirical, and their complete elimination is provided for in the discussion. In the case of *Victoria*, however, the triangulation of the comparison stars and the use of a more accurately computed ephemeris made it possible to determine the absolute positions of the planet with great accuracy. Examination showed that the corrections required by the ephemeris had a period of twenty-seven days, and that the maxima and minima occurred when the Moon's geocentric longitude differed 90° from that of the planet. This showed an error in the lunar equation of the Earth's motion, and furnished a correction to this term.

(A determination of the Sun's parallax from the meridian observations of *Victoria*, *Sappho*, and *Iris*, by Dr. Auwers, is also given. The results from the three planets are discordant, and the weight of the result is very small.)

The results of the three heliometer determinations are :

	π	Prob. Error.
From Victoria (Gill)	8″·8013	± ″·0061
Sappho (Gill)	8·7981	± ·0114
Iris (Elkin)	8·8120	± ·0090
Mean ...	8·8036	± ·0046

That these three independent results agree within the limits of their probable errors affords strong evidence that they are free from systematic error. Two possible sources of systematic error are briefly considered by Dr. Gill : (1) *Errors in the elements of the orbits.* For *Iris* Dr. Elkin found the effect of a difference in the log. distance between the ephemeris he used and that given in the Berlin ephemeris ; as the latter had correctly represented the observations of the planet for a considerable time it was assumed that it could not be much in error, and a correction ″·003 was applied to the parallax deduced by the use of an ephemeris which only represented the position of the planet during the opposition of 1888–9. The ephemerides of *Victoria* and *Sappho* have represented the observations for a considerable time, and it is therefore assumed that their elements require no correc-

tions of amount sufficient to affect the parallax. (2) *A difference in the mean refrangibility of the light of the planets and their comparison stars.* Professor Newcomb says: "If the difference between the spectra of a minor planet and a comparison star is such that the means of their respective visible spectra, or the apparent amounts of their respective refractions, differ by one-tenth of the space between D and E, an error of $0''{\cdot}02$ or $0''{\cdot}03$ may be produced in the apparent parallax of the planet." Dr. Gill remarks on this that it is impossible to distinguish *Victoria* and *Sappho* from the average fixed star of similar magnitude when they are placed near together in the field of the heliometer, and considers that a mean visual difference of colour much less than one-tenth of that between D and E would be readily distinguishable under such a test. Dr. Elkin remarked that the light of *Iris* was slightly less refrangible than that of the stars, but the difference of colour appears to have been very slight. Giving half weight to the *Iris* determination on this account, the value $\pi = 8''{\cdot}802$ with a probable error of $\pm''{\cdot}005$ is given as the final result of the discussion. With this value of the parallax the reciprocal of the mass of the Moon determined from the *Victoria* observations is $1/M = 81{\cdot}702 \pm 094$.

Dr. Gill briefly criticises other methods of determining the Sun's parallax, and considers that it is not legitimate to use the aberration constant for this purpose till a satisfactory physical theory has been put forward. It may be argued, however, that the assumed law of aberration agrees sufficiently closely with the facts to warrant a belief in its *exact* truth, and if this view be taken, aberration furnishes an excellent method of obtaining the Sun's parallax, fairly comparable with Dr. Gill's purely geometric method.

In these two large volumes Dr. Gill has given full details of the numerous observations on which his research is founded, and a clear exposition of his methods. He is to be heartily congratulated on the highly satisfactory conclusion of his arduous undertaking.

The Constant of Precession.

In vol. vii. of the Astronomical papers prepared for the use of the American Ephemeris, Professor Newcomb makes a re-determination of the value of the precession from the proper motions Dr. Auwers obtained by comparison of his re-reduction of Bradley's observations with the Greenwich Catalogues of 1860 and 1865. Systematic corrections are applied to these proper motions to reduce them to the system of Newcomb's "Catalogue of 1080 Fundamental Stars," the most important part of the corrections to the right ascensions arising from $-^{s}{\cdot}079$ applied to the equinox of Auwers-Bradley and $+^{s}{\cdot}024$ applied to the Catalogues of 1860

and 1865. To obtain a criterion as to what stars had best be rejected on account of their large proper motions, a classification is made for stars of different magnitudes according to the size of their proper motions, and the number of stars in each class compared with the number there would be if the distribution were according to the least-squares law. Out of 3181 stars 654 are excluded, and Professor Newcomb concludes from the discussion that more than one-third of the Bradley stars have no proper motion except what is due to the movement of the Sun, and that nearly all of them are included in a sphere whose radius would correspond to a parallactic motion of 2″ per century. Several different methods of treatment are employed in view of the difficulty of eliminating the solar motion, and the possibility of groups of stars having a common proper motion. These methods give accordant results, as also do the stars of different magnitudes, but the result obtained from right ascensions is 1″ per century different from that obtained from declinations, and, further, the latter differs considerably from the result obtained by L. Struve from the same data.

Further examination fails to show any inaccuracy in the result derived from the declinations, which is accordingly accepted. The right ascension result can be made to agree more closely with this by assuming a common motion in right ascension for the fundamental stars; the Greenwich Sun observations, 1835–1895, give a value of about 0″·5 per century for this, and, balancing the evidence, a correction of 0″·30 is adopted.

The values finally obtained as compared with the values of Struve-Peters now in general use are for epoch 1850

	General Precession.	m	n
	″	″	″
Newcomb	50·2453	46·0711	20·0511
Struve-Peters	50·2522	46·0763	20·0564

Some discussion has taken place in the *Astronomical Journal* as to the wisdom of substituting Professor Newcomb's value for that of Struve-Peters in the National Ephemerides, as proposed by the Paris Conference of 1896 May.

Latitude Variation.

The motion of the pole deduced by Dr. Chandler from an exhaustive discussion of observations, irrespective of theory, has been resolved into a combination of two separate motions, one an annual motion from west to east of the terrestrial pole in a very eccentric ellipse about its mean position, the principal axis being 0″·30 and 0″·08, the major axis lying on a meridian

45° east of the Greenwich meridian, and the pole reaching the extremities of this axis on April 6 and October 5 ; the second is circular, with a period of 427 days and a variable radius. The elements of the annual period have been based entirely on recent data from observations between 1889·0 and 1894·0, while the elements of the second period have been derived from observations extending over the years 1825–90. In *Ast. Journ.*, No. 392, he has given a table of the motion of the pole for 1897 at Greenwich, Pulkova, Berlin, Paris, and Washington, and confidently predicts that when the observations made during this year are reduced, his theory will be found to agree within the limits of accuracy to be obtained by the most refined methods at a series of stations specially adapted for the purpose. In *Ast. Journ.*, No. 402, Dr. Chandler has discussed the series of observations specially made between 1894 January and 1895 August at Kazan, Potsdam, Karlsruhe, Strassburg, Bethlehem, and Columbia, and finds that the results conclusively prove the reality of the annual motion and its large eccentricity, and give no evidence of any progressive changes in its value. These latest observations likewise confirm the diminution in the value of the radius of the circular motion, the law for which was previously announced in *Ast. Journ.*, No. 322. Finally, in *Ast. Journ.*, No. 406, Dr. Chandler has placed in a succinct form the mathematical relations involved in the problem that a pole of rotation has a motion relative to the pole of figure, which may be resolved into two components, one an ellipse with a mean period of a year, the other a circle with a mean period of 428·6 days.

W. G. T.

Professor Barnard's Dimensions of the Planets.

While at the Lick Observatory, Professor Barnard made an extensive series of micrometrical measures of the planets. Many of these measures have been given from time to time in the *Monthly Notices*, the *Astronomical Journal*, and other publications, but the results so published have in some cases been preliminary values only. Professor Barnard has now collated and reduced his observations and in *Popular Astronomy*, No. 46, he gives the final adopted values of his measures. These are summarised in the following table :—

Name of Planet.	Diameter in seconds of arc.	Distance to which the diameters in arc are reduced, the mean distance Sun-earth being unity.	Diameter in English miles.
Mercury	6″·126	1	2,765
Venus	17·397	1	7,826
Mars (equatorial)	9·673	1	4,352
,, (polar)	9·581	1	4,312
Ceres	1·076	1	485
Pallas	0·675	1	304
Juno	0·263	1	118
Vesta	0·540	1	243
Jupiter (equatorial)	38·522	5·20	90,190
,, (polar)	36·112	5·20	84,570
Jupiter's Satellites:			
Satellite I.	1·048	5·20	2,452
,, II.	0·874	5·20	2,045
,, III.	1·521	5·20	3,558
,, IV.	1·430	5·20	3,345
Saturn (equatorial)	17·798	9·5389	76,470
,, (polar)	16·246	9·5389	69,780
,, outer diameter, outer ring	40·186	9·5389	172,610
,, inner ,, ,,	35·034	9·5389	150,480
,, centre Cassini division ...	34·517	9·5389	148,260
,, outer diameter, inner ring	34·000	9·5389	145,990
,, inner ,, ,,	25·626	9·5389	110,070
,, ,, ,, crape ring	20·528	9·5389	88,190
,, diameter of satellite Titan	0·633	9·5389	2,720
Uranus	4·040	19·1833	34,900
Neptune	2·433	30·0551	32,900

The measures of *Mercury* above given were made during the transits of 1891 and 1894 with the 12-inch refractor reduced in aperture to 4 inches in 1891, and to 5 inches and 6 inches in 1894. The measures of all the other planets and satellites were made with the 36-inch refractor.

The Atmospheres of Planets and Satellites.

In a paper "On the Physical Constitution of the Sun and Stars" in No. 105 (1868) of the *Proceedings of the Royal Society*, Dr. Johnstone Stoney applied the kinetic theory of gases to the

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interpretation of some of the phenomena of atmospheres. He subsequently extended these investigations; and in a recent memoir published in the *Scientific Transactions of the Royal Dublin Society*, vol. vi. p. 305, "On Atmospheres upon Planets and Satellites," he has given an account of communications made to that Society, in which he explains the absence of hydrogen and helium from the Earth's atmosphere, and the absence of all known constituents of an atmosphere from the Moon, by showing that in accordance with the kinetic theory these gases are so circumstanced on the Earth and Moon that their molecules can drift away; and he further arrives at the conclusion that the same theory implies that the vapour of water cannot be a constituent of the atmospheres of either *Mercury* or *Mars*. The conditions which prevail upon *Mars* are specially discussed.

The investigation also offers an explanation of such a gap in the series of chemical elements as we find upon the Earth between hydrogen and helium, and between helium and lithium; and it shows that if the suspected intermediate elements exist, the conditions upon *Jupiter* are such that they may all be present in his atmosphere, and that some of them may be present upon *Saturn*, *Uranus*, and *Neptune*, though not upon any of the group of four smaller inner planets to which the Earth belongs.

By an application of the same method of investigation to the satellites and the minor planets of the solar system Dr. Stoney infers that there can be no atmosphere upon any of these bodies, except perhaps on the great satellite of *Neptune*.

Finally, the investigation leads to the conclusion that the molecules of the gases which have from time to time escaped from planets or satellites have but seldom been able to extricate themselves altogether from the solar system, and are accordingly for the most part now circulating round the Sun, like excessively minute independent planets.

Star Catalogues.

Auwers' Catalogue of Reference Stars for the Southern Zone Observations of the A.G.C.—In *A.N.*, No. 3431, Dr. Auwers has published a catalogue of "Anhaltsterne" for zone observations in the southern heavens. The catalogue, which is for the epoch 1900, contains 480 stars and 24 close polars, and extends from $-20°$ to the S. Pole. All available material from 1860 to 1895 has been used in its preparation. The adopted equinox is that of the A.G.C., and the declinations are reduced to the same system as the "Catalogue of 303 Fundamental Stars for Southern Zone Observations," already given by Dr. Auwers, which differs from the A.G.C. system by $+0''{\cdot}50 - 0''{\cdot}02 \times \delta°$, and agrees closely with Auwers' Mean System, given in *A.N.*, No. 1536.

Gilliss' Catalogue of Southern Stars.—In the *Washington Observations* for 1890 is published a catalogue of 16,748 southern

stars for the epoch 1850. The observations for this catalogue were made under the direction of the U.S. Naval Observatory by Captain Gilliss during the years 1849–52. The stars observed are confined to the region within 25° of the S. Pole, and were made with a 4½-inch meridian circle by Pistor and Martins. The total number of observations is about 27,000, so that about half the stars have been observed only once, and not many more than twice. Captain Gilliss with a staff of computers worked at the reductions till his death in 1865, shortly after which the computations were stopped, and the papers remained untouched for twenty-five years in the U.S. Naval Observatory ; and it was not till 1890, when Professor S. J. Brown and the late Professor Edgar Frisby were appointed to superintend the completion of the work, that efforts were made to deal with the accumulated material.

Catalogue de 382 *Etoiles faibles de la Zone DM*+2°.—In the volume of *Brussels Observations* for 1896, Dr. L. de Ball has published a small catalogue of faint stars between 9·0–9·5 magnitudes, which were not re-observed in the *Astronomische Gesellschaft* Catalogue for the parallel +2°. He started with the idea of extending his observations to all the stars in the *Bonn Durchmusterung* for these magnitudes, but finding that photography was a much better method for finding the places of such stars, he has relinquished his original design and published the results he has obtained.

Catalogo di 2491 *Stelle Australi nel parallelo* 20° *Australe* (1855.0) *Modena*.—For the same magnitudes Professors Millosevich and Peyra, at the Royal Observatory at Rome, have observed all stars between the parallels of −20° and −21° which had been previously observed in Schönfeld's zones. Between 1895 March and the end of 1896 over 5000 observations were made of some 2491 stars, which have been reduced to the epoch 1895, and published without any loss of time.

Cambridge Zone Catalogue.—This catalogue contains 14,464 stars between 24° 15′ and 30° 57′ N. declination. The transits were observed by the eye and ear method by Mr. Graham ; the readings of the circle were made by Mr. Todd, two microscopes being used. As in the other zone observations of the *Astronomische Gesellschaft*, the right ascensions and declinations depend on those of standard stars. An account of the Catalogue is given in the Report of the Cambridge Observatory to the Council.

Catalogue de l'Observatoire de Paris.—The third volume of the *Paris Catalogue* (from 12^h to 18^h) giving the results of observations made at the Paris Observatory from 1837 to 1881, appeared during the year. The observations from 1837 to 1853 are reduced to the epoch 1845, those from 1854 to 1867 to the epoch 1860, and those 1868 to 1871 to the epoch 1875·0. The observations are compared with Lalande, and for those stars which show considerable differences the proper motions are deduced by extensive comparisons with a large number of catalogues.

Catalogue des Mouvements propres de 2641 étoiles.—In the *Annales de l'Observatoire de Paris* for 1888, published in 1896, M. J. Bossert has collected together a list of 2641 stars whose proper motions exceed $0^s{\cdot}010$ in right ascension, and $0''{\cdot}10$ in declination, and the observations of which extend over fifty years. M. J. Bossert appears to have exhausted all the most modern material for his compilation, so that his list may be considered quite up to date as far as it goes. The proper motions in right ascension are given to three, and in declination to two places, and in many cases are determined from three authorities, which are in all cases plainly stated. His avowed object in making the list is to draw the attention of astronomers to these particular stars, and astronomers can only be thankful to M. Bossert for the trouble and labour which has put in their hands such a useful desideratum.

W. G. T.

Double Stars.

The report is, as in former years, considered under the two heads—Observation and Calculation.

Observation.—First list of new pairs (78) discovered at the Cape Observatory by Mr. Innes with the 7-inch refractor ...	*A.N.* 3406
Second list of 149 new pairs	*M.N.* May
Third list of 60 new pairs	*A.N.* 3438
Fourth list of 29 new pairs...	*A.N.* 3462
α Phœnicis, π Phœnicis, μ Velorum, β Lupi, η Centauri announced double by Dr. See	*P.A.* March
Mesures micrométriques d'étoiles doubles faites à St-Pétersbourg et à Domkino, by Professor Glasenapp in 1895	
Measures of 86 pairs with 36-inch Lick Refractor by Professor Hussey	*A.J.* 397
„ „ 32 Struve pairs with 12-inch refractor at Morrison—Pritchett (1896)	*A.J.* 397
„ „ 8 wide pairs by M. Eichelberger	*A.J.* 397
„ „ 92 special pairs with $10\frac{1}{2}$-inch at University Observatory, Minnesota—Leavenworth ...	*A.J.* 407
„ „ 25 pairs—S. B. Saulè, ditto ...	*A.J.* 410
„ „ 3 pairs—Mary Wagner, ditto...	*A.J.* 410
„ „ 26 pairs, whose orbits appear in Dr. See's "Evolution of Stellar Systems," by Eric Doolittle with 18-inch at Flower Observatory ...	*A.J.* 416

Measures of 56 wide pairs ($O\Sigma^2$)—Franz ...		*A.N.* 3464
,, ,, Struve pairs by MM. Charfordet and Petit (Besançon) ...		*A.N.* 3450; *B.A.* 1897 Nov.
,, ,, 31 pairs by J. L. Scott ...		*B.A.J.* vii. 2
,, ,, 13 Struve pairs by Lehman with 12-inch Lick Refractor ...		*A.S.P.* No. 56
,, ,, double stars in the cluster surrounding *η Carinæ*—T. J. J. See		*M.N.* May
,, ,, 8 pairs—Mr. Tebbutt		*M.N.* June
,, ,, a large number of pairs by Aitken at Lick		*A.N.* 3465–6
,, ,, pairs by Dr. Doberck ...		*A.N.* 3465–6
,, ,, small stars near *Sirius*—Barnard		*A.J.* 420
,, ,, companion to *Sirius*—Schæberle		*A.J.* 394, 420
,, ,, ,, ,,	Aitken...	*A.J.* 415; *A.S.P.* 55, 59
,, ,, ,, ,,	See ...	*A.J.* 418; *A.N.* 3469
,, ,, ,, *Procyon*—Schæberle		*A.J.* 394, 416, 420
,, ,, ,, ,,	Aitken...	*A.J.* 394; *A.S.P.* 54
,, ,, ,, ,,	Hussey...	*A.S.P.* No. 56
,, ,, *β* 883 and *β* 552	Aitken...	*A.S.* 415
,, ,, *β* 733	Schæberle	*A.J.* 420
,, ,, companions to *Vega*—Barnard		*A.J.* 414
,, ,, ,, ,,	Schæberle	*A.J.* 418
,, ,, 70 *Ophiuchi*	Pritchett	*A.J.* 411
,, ,, ,, ,,	Schur ...	*A.N.* 3405
,, ,, ,, ,,	See ...	*A.J.*

Calculation.—The following orbits have been computed during the year :—

	Period.	Semi-axis Mag.	Reference.
Sirius	51·8	7·62	*M.N.* April
β 883	5·5	0·76	*M.N.* June
β 395	16·3	0·57	*A.N.* 3455
μ^2 Boötis	275·7	1·48	*A.N.* 3441
$O\Sigma$ 400	85.		*M.N.* Jan. 1898

and other works are :—

The orbit of *Sirius* compared with recent Observations—T. J. J. See	*A.J.* 418
Note on the orbit of *Sirius*—Mann ...	*P.A.* March
Note on the pair 44 *Boötis*—Burnham ...	*M.N.* March
,, ,, *δ Cygni* ,, ...	*M.N.* April

Note on the pair	μ *Draconis*	Burnham	...	*M.N.* May
,, ,,	ζ *Boötis*	,,	...	*M.N.* Jan. 1898
,, ,,	OΣ 215	,,	...	*P.A.* April
,, ,,	Σ 1687	,,	...	*P.A.* April
,, ,,	λ *Cygni*	,,	...	*P.A.* Feb.
,, ,,	Σ 2909	,,	...	*P.A.* March
,, ,,	OΣ 4	,,	...	*P.A.* July
,, ,,	Σ 1216	,,	...	*P.A.* Jan. 1898
,, ,,	Σ 2107	,,	...	*P.A.* Jan. 1898
,, ,,	ξ 3638	See	...	*M.N.* March
,, ,,	γ *Lupi*	,,	...	*M.N.* Nov.
,, ,,	ξ 5014	,,	...	*M.N.* Dec.
,, ,,	ξ 4707	Innes	...	*Obs.* Oct.
,, ,,	κ *Toucani*		...	*M.N.* April
,, ,,	ξ 3941 and	Stone 3480	...	*B.A.J.* vii. 9
,, ,,	ξ 4935		...	*M.N.* Jan. 1898
Remarks on double stars discovered at Arequipa—Innes			...	*A.J.* 417
General remarks on double stars ...			...	*Obs.* May
The spectra of binary stars... ...			...	*Obs.* March

The abbreviations are :—

M.N. Monthly Notices R.A.S.
A.N. Astronomische Nachrichten.
A.J. Astronomical Journal.
P.A. Popular Astronomy.
Obs. The Observatory.
B.A.J. Journal of the B.A.A.
A.S.P. Journal of Astron. Society of the Pacific.
B.A. Bulletin Astronomique.

T. L.

Variable Stars.

During the year the progress in this branch of astronomy has been very marked. If we consider merely the number of new variables discovered, the amount is out of all proportion greater than that discovered in any former year.

The Harvard Observatory announces in *Astronomische Nachrichten*, No. 3444, the discovery of no fewer than 310 variable stars in certain southern globular clusters. In one of the clusters, Messier 3, there is stated to be 113 variable stars—that is, one-ninth of the whole number of stars in the cluster is variable. It is to be hoped that close and continuous observation will be made of all these variables to determine if there be any similarity of period, amplitude or type of variation.

Professor Pickering, in *Ast. Nach.* No. 3422, announces the discovery of three southern variables, the variation being detected by examination of their spectra.

From the Cape Observatory we have during 1897 the announcement of sixteen new variables ; the variation being discovered, in the first instance, either by a comparison of the magnitudes in the Cape *Photographic Durchmusterung* and the

Cordoba *Durchmusterung*, or by examination of Cape photographic plates taken at different dates.

In nearly every instance independent confirmation of variation by visual estimates is certified by Mr. R. T. A. Innes, who, in this branch of astronomy, as well as in the discovery of double stars, has done work conspicuously characterised by accuracy and zeal. Detailed information concerning the stars is to be found in *Ast. Nach.*, Nos., 3426, 3441, 3447, 3453.

Mr. Stanley Williams, in *Ast. Nach.*, Nos. 3,440, 3,450, gives a list of thirteen southern stars which observations made by him in 1885–1886 indicate to be variable. A comparison between the magnitudes recorded in the Southern Meridian Photometry and the magnitudes recorded in the *Uranometria Argentina* goes far to confirm the variation of several of these stars.

Dr. Thos. D. Anderson announces in *Ast. Nach.*, Nos. 3394, 3433, 3440, 3461, 3463, and 3467, the discovery of seven new variables. The variation of two of these stars —one in the constellation *Andromeda* and one in *Hercules*—has been confirmed by Parkhurst and Yendell.

The announcement is also made of the discovery of a new variable in *Virgo* by Mr. Arthur J. Roy, and one in *Puppis* by Mr. Arthur C. Perry.

Professor F. Deichmüller, in *Ast. Nach.*, No. 3447, gives particulars of a new variable in *Lacerta.*

A valuable link between the Cordoba observations (1871–78) of southern variable stars and those made in recent years is furnished by Mr. Stanley Williams, who, in the *Astronomical Journal*, No. 417, gives his observations of southern variable stars made in 1885 and 1886.

Mr. Williams also brings forward an interesting fact concerning the southern variable Lac 3105. Mr. Williams, on announcing the variation of the star some years ago, gave as its period $4\frac{1}{2}$ days. Subsequent observation by other observers indicated a much shorter period than this. In *Ast. Nach.*, No. 3391, Professor Pickering announces that he finds Lac 3105 to be a spectroscopic binary with a period of 3·115 days; and Mr. Williams in No. 3410 states that half this period, or 1·558 days, will satisfy all his observations.

In the *Astronomical Journal*, No. 413, Mr. W. E. Sperra confirms the discovery made at Harvard as to the non-Algol nature of the variation of *S Antliæ.*

This star must now definitely be considered as belonging to the short period (II.) class.

Important definitive determinations of the light changes of *β Lyræ* and *η Aquilæ* have been made during the year. In the *Koninklijke Akademie van Wetenschappen te Amsterdam*, vol. v. No. 7, Herr Pannekoek gives the results of his investigations of *β Lyræ.*

He finds the following elements of principal minima :—

1855 Jan. 6·604 G.M.T. + 12·908009 E
+ 0·000003855 E^2 − 0·000000000047 E^3.

The times between the principal phenomena of the light changes are as follows :—

	1842-1870. d	1870-1895. d
From Prin. Min. to 1st Max.	3·12	3·32
to 2nd Min.	6·40	6·48
to 2nd Max.	9·54	9·73

These facts would seem to indicate an almost circular orbit. In connection with this investigation must be mentioned the important spectroscopic researches on the orbital motion of the star by M. Belopolsky. M. Belopolsky finds that the radial velocity is zero when the star is passing either through its primary or secondary minimum. This conclusive proof of the chief cause of the variation of *β Lyræ* is most satisfactory. The smallness of the eccentricity found is also in keeping with the practically equal periods between the two maxima and two minima.

A definitive determination of the variation of *η Aquilæ* has been completed by Dr. W. J. S. Lockyer, who finds the light period to vary between $7^d\ 4^h\ 14^m\ 40^s$ and $7^d\ 4^h\ 13^m\ 28^s$ in 2400 periods. Dr. Lockyer also finds a decided oscillation in the time of maxima to the extent of 5 hours with a period comprising 400 maxima.

As in the case of *β Lyræ* we have recently a spectroscopic investigation of the orbital movement of *η Aquilæ* by M. Belopolsky. The investigation is to be found in the *Memorie della Società degli Spettroscopisti Italiani*, No. 7. Two important conclusions follow from this investigation. If both *η Aquilæ* and *δ Cephei*, typical stars of the short-period class, be binaries, duplicity is common to the whole class. Further, M. Belopolsky finds that in *η Aquilæ*, as in *ε Cephei*, the zero of radial velocity does *not*, as it does in the case of the Algol star *β Lyræ*, take place when the star passes through its minimum phase. Eclipse accordingly is not the primary cause of the star's variation. The higher eccentricity of these two stars, the maximum phase taking place soon after periastron, point clearly in the direction to which we must look for an explanation of the phenomenon of short-period variation.

The variable star observations of the late Mr. George Knott, comprising observations of 23 variables, are now in the press, and will form a volume of the *Memoirs* of the Society.

A. W. R.

Spectroscopic Astronomy in 1897.

An announcement made by Professor E. C. Pickering in 1897 January will probably make the year memorable in the history of spectroscopes, inasmuch as it deals with a discovery which promises to lead to an extension of our knowledge of the spectrum of hydrogen.

Pickering had previously announced that in the spectrum of the star ζ *Puppis* there was, in addition to the well-known series of hydrogen lines, a rhythmical series of lines of unknown origin. In his later note (*Astrophysical Journal*, vol. v. p. 95) he points out that the wave-lengths of the lines of the new series are connected by a formula of the usual type, and moreover that a formula can be found which is identical with that connecting the wave-lengths of the hydrogen lines ; the new series being deduced by taking odd values of n, the known (hydrogen) series by taking even values. The new lines alternate with the hydrogen lines, and the new series converges to the same point in the ultra violet as the hydrogen series. Professor Pickering's expectation, that the new series are attributable to hydrogen, is already shared by many authorities in spectroscopy. The search for means of exciting in the spectrum of terrestrial hydrogen the new series of lines will be doubly interesting, for it seems not unlikely that it may lead to the discovery of yet another series of lines—the "principal" series of hydrogen.

An important paper (*Proc. R. S.* vol. lxi. pp. 148–209) by Sir Norman Lockyer was made the subject of a discussion at the Royal Society towards the end of February. The paper is an elaboration of the author's view that in the evolution of stars as evidenced by their spectra "the only variable of paramount importance is temperature" (*loc. cit.* p. 150). From a study of the admirable photographs of stellar spectra obtained at South Kensington, Lockyer is led to conclude that if the spectra of different stars are arranged in order of the extension of the continuous spectrum with the ultra violet—that is, in order of temperature, according to the usual view—then a regular sequence in the appearance and disappearance of the absorption lines of certain elements may be traced. The lines of the cleveite gases appear only in the spectra of stars which exhibit great extension of continuous radiation into the ultra violet. A diminution of the extension into the ultra violet is accompanied by a weakening of the lines of the cleveite gases and a relative intensification of certain metallic absorption lines which Lockyer has called enhanced lines. With a further diminution of the extension into the ultra violet the enhanced lines die out, and the metallic absorption lines corresponding with the ordinary arc spectra of the metals become prominent. The enhancement of lines in passing from the arc spectrum to the spark spectrum of a metal is ascribed by Lockyer to the difference of temperature ; and he finds that the order of temperature of certain stars, as determined

from a comparison of the extensions of the continuous spectrum is the same as that which follows from a comparison of the metallic spectra at four stages of temperature—viz. the temperature of the flame spectrum, of the arc spectrum, of the spark spectrum, and of a spectrum consisting solely of those lines which are enhanced in passing from the arc to the spark. It is beyond the scope of the present note to do more than record in the briefest manner the publication of Sir Norman Lockyer's very suggestive paper.

An abstract of the remarks made by Professor Schuster in the course of the discussion is published in the same number of the *Proceedings of the Royal Society*, and forms an exceedingly valuable commentary on the paper.

Father Sidgreaves makes another valuable contribution to the study of the spectrum of β *Lyræ* (*Monthly Notices*, vol. lvii. pp. 515–531), giving special attention to thirteen lines or groups of lines in the spectrum. This work has been accomplished with the Father Perry Memorial instrument at the Stonyhurst College Observatory. Eighty-eight photographs of the spectrum, taken between 1895 May and November, are utilised in the discussion, and the varying behaviour of the bright lines is noted with respect to the time-interval from the preceding principal minimum in the cycle of the star's variation of brightness. The difference in the behaviour of the two hydrogen lines Hβ and Hγ seems to deserve further attention.

A remarkable piece of work, forming part of the Henry Draper Memorial, has recently appeared—viz. vol. xxviii., Pt. 1, of the *Annals of the Harvard College Observatory*. It contains the results of the examination (carried out by Miss A. C. Maury, under the direction of Professor E. C. Pickering) of 4800 photographs relating to the spectra of 681 bright stars north of declination $-30°$, and forms a new classification of stellar spectra. The spectra are arranged in a progressive series of twenty-two groups, starting with stars of the *Orion* type, and passing by almost insensible steps through five types.

In the publication of a short note in June on "Some determinations of velocity in the line of light," Mr. H. F. Newall has given (*Monthly Notices*, vol. lvii. pp. 567–577) a sign of the successful inauguration of an important piece of work at the Cambridge Observatory. The determinations have been made from photographs, the stellar spectra being photographed between iron comparison spectra. Examples of results are given in the paper, and a comparison with Dr. Vogel's work, in which hydrogen was used for the standard line, shows that the different methods lead to the same result.

In a paper read before the Royal Society in June, Sir William and Lady Huggins describe a set of experiments which show that by sufficiently diminishing the quantity of calcium on two terminals between which an electric spark passes, the spectrum of the spark may be reduced, so far as calcium is concerned, to a

spectrum of two lines corresponding with the lines H and K. This experimental result, taken in connection with the fact that the lines H and K are the sole representatives of the calcium spectrum in many extensive prominences, constitutes a definite advance in solar physics. It has long been recognised that by decreasing the *quantity* of incandescent vapour the number of lines in the spectrum of an element may be reduced till only one or two lines are visible, but it appears that it has never been actually determined which line or lines are the most persistent in the case of calcium.

The Longitude of Madras.

Warren's Longitude of Madras, on which the longitudes of the Indian Survey Maps depend, is known to be about $2\frac{1}{2}'$ too large, and a re-determination by Captains S. G. Burrard and Lenox Conyngham, who had been engaged in determining the astronomical longitudes of certain stations in Persia, was made in the year 1895. The difference of longitude of Greenwich and Karachi, a principal western station of the Indian Survey, whose longitude west of Madras is therefore well known, was published in 1897.

The arcs which make up the chain will be seen from enumeration of the following observing stations: Karachi, Bushire, Teheran, Potsdam, Greenwich. Besides these, Jask, on the Persian Gulf, was also a station, and the arcs Karachi—Jask, Jask—Bushire were determined, so that, as these three stations form a circuit, a check is supplied to the determination of the arc Karachi—Bushire. Noteworthy points about this chain are, first, that the arc Teheran to Potsdam is very long, remembering that these places were connected almost entirely by a land line. The actual length is 2626 miles of land line, with two miles of cable inserted, and on this long line only one translation by relay was made. It was a little unfortunate, Captain Lenox Conyngham points out, that this had to be at Odessa, which is by no means the middle point of the line. The other point is that between Potsdam and Greenwich no relays were used, but the land lines were joined direct to the cable at Emden and at Lowestoft. It was suggested by Mr. Preece, the Engineer-in-Chief of the Post Office, that not only would this arrangement be possible, but that by having lengths of land line at either end of the cable the retardation time would be more likely to be the same in both directions than if the cable were joined to a single land line. This consideration, as well as a suggestion by the Astronomer Royal that it would be advisable to make Potsdam a station, induced Captain Burrard to modify the chain originally planned, in which the eastern stations were Greenwich, Lowestoft, Emden, Odessa.

It is not necessary here to follow the details of the work,

beyond saying that on the arc Potsdam—Greenwich the observers interchanged stations, so that the value of this arc is free from personal equation, if we may assume that neither observer changed his habit during the work. In determining the arcs Teheran—Potsdam, Teheran—Bushire, Captain Lenox Conyngham was in both cases at Teheran, so that the algebraic sum which gives the difference of longitude between Bushire and Potsdam is also not affected by personality, and although on the arc Karachi—Bushire personality was not eliminated, as has been said, this arc forms part of a circuit, and its value is therefore determined with additional weight.

The whole work, including in it the value of the arc Madras—Karachi from the volumes of the Indian Survey, gives as the longitude of Madras east of Greenwich $5^h\ 20^m\ 59^s{\cdot}113$ with a probable error $\pm 0^s{\cdot}0227$, which shows the error of the Indian triangulation to be $+2'27''{\cdot}54$. There are now five telegraphic determinations of the longitude of Madras, the results of which it may be of interest to compare. The first of these was partly made by the English observers of the transit of *Venus* in 1874, who determined the longitude of Suez from Greenwich. The arc from Suez to Madras was measured later by officers of the Indian Survey. About the same time the German observers of the transit of *Venus* with General Addison at Karachi and Mr. Pogson at Madras measured a chain *via* Ispahan and Berlin. Subsequently Dr. Gill and Dr. Auwers measured the arc Aden—Berlin, which with the before-mentioned links, Berlin—Greenwich and Madras—Aden, complete another chain. A fourth value results from a Russian determination of the longitude of Vladivostok combined with a series of arcs connecting that place with Madras, measured by officers of the U.S. Navy. The first results of these—for it should be said that all have been modified by subsequent discussion—are as follows :—

	Route *via*	h	m	s
(A)	Suez and Aden	5	20	59·416
(B)	Berlin and Ispahan	5	20	59·65
(C)	Berlin and Aden	5	20	59·041*
(D)	Pulkowa and Vladivostok	5	20	59·750
(E)	Present determination	5	20	59·113

The later discussions of the same chains result as follows :—

	h	m	s		h	m	s
(A) ...	5	29	59·422	(C) ...	5	20	59·233†
(B) ...	5	29	59·01†	(D) ...	5	20	59·452‡

As some explanation of the large differences shown by these results, it may be said that the arc by Dr. Gill and Dr.

* Copeland's reduction. † Auwers's reduction.

‡ This value was found by Professor Oudemans from comparison with the results of other chains, and is therefore not independent.

Auwers which forms a link of (C) was measured under circumstances of some difficulty, and this and the difference Greenwich —Suez of the chain (A) were determined by methods that were expected to give results of only minor weight. The chain (D) is the sum of a great number of links by different observers. Remembering that the recent determination was made by the same two observers throughout the chain, in few steps and with the utmost care, it is entitled to much weight in any discussion.

The value of the single arc Potsdam—Greenwich determined by Captain Burrard and Captain Lenox Conyngham is $0^h\ 52^m\ 15^s{\cdot}929$. The value of the longitude of Berlin east of Greenwich determined by German observers was $0^h\ 53^m\ 34^s{\cdot}910$, and the difference of longitude between Berlin and Potsdam has recently been determined with internal evidence of much accuracy as $1^m\ 18^s{\cdot}721$, so that compared with these the above value Potsdam —Greenwich is small by $0^s{\cdot}260$.

H. P. H.

The Yerkes Observatory.

The observatory attached to the University of Chicago, which takes its name from its generous donor, Mr. Charles T. Yerkes, was handed over to the University and formally opened with some ceremony in October 1897. The account of its origin, and of its building and equipment which follows, is mainly abstracted from a series of articles by Professor G. E. Hale, the Director of the Observatory, which appeared in the *Astrophysical Journal*.

The University of Chicago is not of great antiquity. When it began its work in 1892, it was felt that the study of astronomy and astrophysics should form part of its curriculum, and that an effort should be made to procure an observatory. There were then in the workshops of Messrs Alvan Clark two large discs of optical glass of 42 inches diameter, which had been provided to make a large objective for the University of Southern California, but for certain reasons this order had not been completed. Mr. Yerkes, at the suggestion of Mr. Hale, took the opportunity thus offered of procuring a very large object-glass without much delay. He bought the discs, gave orders for these to be fashioned into an objective of 40 inches diameter, and for a suitable tube and equatorial mounting to be made, and then with magnificent generosity, offered this complete instrument, together with the cost of a large observatory building, to the University. Needless to say, the offer was accepted, and after much careful consideration a site was chosen about seventy-five miles from Chicago, on the shore of Williams Bay, Lake Geneva, Wisconsin.

The first excavations for the building were made in 1895

April, and the staff were in residence by 1896 October. The ground floor of the building takes the form of a Latin cross, the central line of which lies east and west, and is 326 feet long. The western end of the central building is formed by the tower supporting the large dome, 90 feet in diameter, which covers the large equatorial; at the other end of the building is the transit room. The transept, very near the eastern end, is terminated at each end by towers, of smaller diameter but higher than the western, which are to carry smaller domes and equatorials. The architecture of the building, for which Mr. Cobb, of Chicago, is responsible, is of Moorish or Saracenic style. The slender pillars and elongated semicircular arches give a light appearance to the huge building, and the domes, which are usually difficult objects to deal with from an artistic point of view, harmonise well with the style of architecture.

To the interior details it is only necessary to refer briefly here. There is an elegant central hall, a heliostat room (which forms the attic of the transept before mentioned), spectroscopic, chemical, and optical laboratories, an instrument shop, photographic rooms, library, and other adjuncts of an observatory. The transit room, which is designed after the pattern of that at the Royal Observatory, Berlin, has walls of double sheet iron with an air space between. For architectural effect, this has an outer casing of a row of columns supporting a rich terra-cotta cornice.

The principal telescope is the 40-inch equatorial. The object-glass for this, made by Messrs. Alvan Clark & Son from the discs furnished by Mantois, of Paris, has focal length of nearly 62 feet. The crown lens is about $2\frac{1}{2}$ in. thick at the centre, and $\frac{3}{4}$ in. at the edge; it weighs 200 lbs. The flint lens, separated from the crown by a distance of $8\frac{3}{8}$ inches, is about $1\frac{1}{2}$ in. thick at the centre, 2 in. at the edge, and weighs over 300 lbs. The lenses are mounted upon aluminium bearings in a cast-iron cell. The mounting and rising floor were made by Messrs. Warner & Swasey, of Ohio. The column supporting the equatorial head is of cast iron, and the height of the top of the head above the lowest position of the rising floor is 43 feet. The polar and declination axes are of hard forged steel, and weigh $3\frac{1}{2}$ tons and $1\frac{1}{2}$ ton respectively. The polar axis is $13\frac{1}{2}$ feet long, and the declination axis $11\frac{1}{2}$ feet. The telescope tube, of sheet steel, is 52 inches in diameter at the centre, 42 inches at the objective end, and 38 inches at the eye end. The instrument is driven by a weight clock, which is wound automatically by an electric motor when the weight is near the limit of its fall, and the clock is controlled by a double conica pendulum. The instrument is supplied with a system of electro-motors to work the slow-motion gear and to clamp and unclamp the telescope, so that the telescope can be controlled with ease by the observer at the eye end. The accessories of the telescope are at present a filar micrometer, the solar spectroscope and spectro-heliograph formerly used at Kenwood, and a stellar spectrograph made by Mr. Brashear.

The other instruments of the observatory consist of the twelve-inch refractor with visual and photographic objectives, which is mounted in the north-east tower, a four-inch concave grating, a clock, and a collection of minor apparatus used at Kenwood. To this it is proposed to add a sixteen-inch refractor which will be placed on the north-west tower and used for micrometric work, and a transit instrument. An equatorially mounted portrait lens is to be set up in a small outbuilding for photographing such objects as comets and nebulæ, and it is proposed to make a sixty-inch mirror in the optical shop of the observatory, which, like the machine shop, is furnished with an elaborate and efficient equipment.

The following gentlemen constitute the observatory staff :— Professor G. E. Hale, Director ; Professors Barnard, Burnham, and Wadsworth, with Mr. G. W. Ritchey in charge of the workshops. The programme of work, as at present arranged, is to a great extent spectroscopic and astrophysical, but micrometrical work on double stars, planets, and satellites has a place.

H. P. H.

Papers read before the Society from March 1897 to January 1898.

1897.

Mar. 12. On the mean motion of lunar perigee and node. E. W. Brown.

On the theoretical values of the secular accelerations in the lunar theory. E. W. Brown.

New double stars found at the Cape Observatory in 1896. Communicated by Dr. D. Gill.

Observations of comets and planets made with the Dun Echt refractor and wire micrometer at the Royal Observatory, Edinburgh, by Dr. J. Halm. Communicated by Dr. R. Copeland.

Micrometrical measures of double stars. W. Coleman.

The nuclei of a sun-spot. T. K. Mellor.

On a new binary of short period in the constellation *Dorado*. T. J. J. See.

Observations taken at Vadsö during the total eclipse of the Sun, 1896 August 9, by passengers of the S.S. *Neptun*. Drawn up and communicated by the Rev. T. C. Porter.

The orbit of δ *Cygni*. S. W. Burnham.

On the curve $y=\left\{\frac{1}{x^2+\sin^2\psi}\right\}^{\frac{3}{2}}$, and its connection with an astronomical problem. Mrs. W. H. Young (Miss Grace Chisholm).

Discordances of index errors of the Madras Mural Circle during the years 1834 to 1842 inclusive. A. M. W. Downing.

On a photographic transit-circle. H. H. Turner.

Further proof of the rotation-period of *Venus*. Percival Lowell.

The spectrum of β *Lyræ* as observed at Stonyhurst College Observatory in 1895. Rev. W. Sidgreaves.

Cloud statistics for stations in India near the path of the Moon's shadow on 1898 January 21–22. A. M. W. Downing.

Ephemeris for physical observations of *Mercury*. A. Marth.

Estimations of the magnitude of *Nova Aurigæ* made at the Radcliffe Observatory, Oxford. E. J. Stone.

Transit-circle observations of Comet Swift (1896 April 13) sub polo, made at the Radcliffe Observatory, Oxford. Communicated by E. J. Stone.

Attempt to photograph the *Leonids* in the open sky. Isaac Roberts.

Apr. 9. A new quadruple stellar system. R. T. A. Innes.

On the straightness of spider lines. H. H. Turner.

Observations of minor planet (8) *Flora* at Windsor, New South Wales. John Tebbutt.

The orbit of *Sirius*. S. W. Burnham.

Micrometrical measures of the double stars in the great nebula and cluster surrounding *η Carinæ*, made with the 24 inch refractor of the Lowell Observatory. T. J. J. See.

On some original observations of the comet of 1652. E. B. Knobel.

On the determination of the epoch-correction of an adopted system of right ascensions of clock stars from observations of the Sun, including the effects of personalities; and applications of the results to the determination of the errors of the tables of the Sun and Moon. E. J. Stone.

An investigation concerning the position error affecting eye estimates of star magnitudes. A. W. Roberts.

Proper motion of the southern short period variables *L Carinæ* and *K Pavonis*. A. W. Roberts.

On the apparent disc and on the shadow of an ellipsoid. A. Marth.

Observations of comets 1896 III. (Swift), and 1896 IV. (Sperra), made at the Radcliffe Observatory, Oxford. Communicated by E. J. Stone.

An improvement in winding equatorial clocks. A. F. Lindemann.

May 14. Preliminary note on a personal equation depending on magnitude affecting the right ascensions of the stars in the Cambridge Zone Catalogue of the *Astronomische Gesellschaft* and its determination from Astrographic Catalogue plates. A. R. Hinks.

Zodiacal radiants of fire-balls. W. F. Denning.

On a new binary star with a period of five and one half years. (β 883). T. J. J. See.

On the mean places and proper motions for 1900 of 24 southern circumpolar stars. David Gill.

On the determination of terrestrial longitudes by photography. Capt. E. H. Hills.

The orbit of μ *Draconis*. S. W. Burnham.

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Observations of comets Perrine 1896 Nov. 2, and Perrine 1896 Dec. 8, made at the Radcliffe Observatory, Oxford. Communicated by E. J. Stone.

Cometary observations at the Liverpool Observatory, 1896. W. E. Plummer.

On the various forms of personal equation in meridian transits of stars. T. H. Safford.

June 11. Theory of the motion of the Moon. E. W. Brown.

Note on the mean motions of the lunar perigee and node. E. W. Brown.

Elements of comet Perrine (*f*) 1896, Nov. 2. C. J. Merfield.

Nebula H I. 43 *Virginis*. K. D. Naegamvala.

The expected shower of *Leonids* in 1897. W. F. Denning.

Results of double star measures with the 8-inch equatorial at Windsor, New South Wales, in 1896. John Tebbutt.

Notes on the reduction of stellar photographs. A. A. Rambaut.

Photographic observations of comet (*b*) 1896. A. A. Rambaut.

Ephemeris for physical observations of the Moon. A. Marth.

On some spectroscopic determinations of velocity in the line of sight made at Cambridge Observatory. H. F. Newall.

Nov. 12. The effect of the general illumination of the sky on the brightness of the field at the focus of a telescope. F. L. O. Wadsworth.

A note on spider lines. F. L. O. Wadsworth.

Catalogue No. 2 of nebulæ discovered at the Lowe Observatory, Echo Mountain, California. Lewis Swift.

Occultation of *Ceres* by the Moon on 1897 November 13, visible at Greenwich. Communicated by the Superintendent of the *Nautical Almanac*.

Personality in measurements of photographs for the Astrographic Catalogue at the University Observatory, Oxford. H. H. Turner.

Observations of *Jupiter* and *Jupiter's* satellites made at Mr. Crossley's Observatory, Bermerside, Halifax. J. Gledhill.

Observations of the physical features of *Mars* made at Mr. Crossley's Observatory, Bermerside, Halifax, during the opposition 1896–97. J. Gledhill.

Note on observations of *Venus* in 1897 (January to April), at Mr. Crossley's Observatory, Bermerside, Halifax. J. Gledhill.

List No. 3 of nebulæ discovered at the Lowe Observatory, Echo Mountain, California. Lewis Swift.

On the nature of the orbit of γ *Lupi*. T. J. J. See.

List No. 4, for 1900·0 of nebulæ discovered at the Lowe Observatory, California. Lewis Swift.

Equatorial Comparisons of *Uranus* with 41 *Libræ*, and a probable occultation of the star by the planet. John Tebbutt.

On the effect of chromatic dispersion of the atmosphere on the parallaxes of α *Centauri* and β *Orionis*; and on a method of determining its effect on the value of the solar parallax derived from heliometer observations of minor planets. David Gill.

The great equatorial current of *Jupiter*. A. Stanley Williams.

Approximate ephemeris of the *Leonids* from 1897 December 24 to 1898 April 8. G. Johnstone Stoney.

A spectroscopic method for determining the second and third contacts during a total eclipse of the sun. William Shackleton.

Occultation of the *Pleiades*, 1897 July 23. W. E. Plummer.

Note on a result concerning diffraction phenomena used by Professor Wadsworth in several recently published papers. H. F. Newall.

On the apparent diurnal motion of stars in relation to the adjustment of the polar axis of a telescope. C. Davidson.

Observations of comet *b* 1897 (Perrine) at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Dec. 10. Occultation of *Ceres* by the Moon on 1897 November 13, observed at the Hamburg Observatory. G. Rümker.

Ephemeris for physical observations of *Jupiter*, 1897-98. A. C. D. Crommelin.

A determination of the latitude variation and of the constant of aberration from observations made at the Royal Observatory, Cape of Good Hope, 1892-94. W. H. Finlay.

The binary star *h* 5014. R. T. A. Innes.

Mean areas and heliographic latitudes of sun-spots in the year 1895, deduced from photographs taken at the Royal Observatory, Greenwich, at Dehra Dûn (India), and in Mauritius. Communicated by the Astronomer Royal.

Additional note on personal equation. T. H. Safford.

Proper motions of the three close polar stars Groom-

bridge 1119, 2283, and 3548. Communicated by the Astronomer Royal.

Observations of meteors on 1897 November 13–15, made at the Radcliffe Observatory, Oxford. Communicated by the Radcliffe Observer.

Occultation of the planet *Ceres* by the Moon on 1897 November 13. Communicated by the Radcliffe Observer.

1898.

Jan. 14. The ternary system Lac. 7215=*h* 4935. R. T. A. Innes.

The double star *ζBoötis*, Σ 1865. S. W. Burnham.

The orbit of OΣ 400. S. W. Burnham.

A note on the result concerning diffraction phenomena recently criticised by Mr. Newall. F. L. O. Wadsworth.

Observations of occultations of stars by the Moon, and of the phenomena of *Jupiter's* satellites, made in the year 1897 at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Occultations of the *Pleiades* by the Moon on 1897 July 23 and 1898 January 3, made at the Radcliffe Observatory, Oxford. Communicated by the Radcliffe Observer.

Ephemeris for physical observations of *Jupiter*, 1898. A. C. D. Crommelin.

On the parallax of *Sirius* and *α Gruis*. David Gill.

List of Public Institutions and of Persons who have contributed to the Library, &c., since the last Anniversary.

The Lords Commissioners of the Admiralty.
The French Government.
The Netherlands Government.
The Norwegian Government.
British Association for the Advancement of Science.
British Astronomical Association.
British Horological Institute.
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City of London College.
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London Mathematical Society.
Meteorological Office.
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Dublin, Royal Society.
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Leeds Astronomical Society.
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Liverpool Observatory.
Manchester Literary and Philosophical Society.

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Rugby School Natural History Society.
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Australasian Association for the Advancement of Science.
Baltimore, Johns Hopkins University.
Batavia, Magnetical and Meteorological Observatory.
Batavia, Royal Society of Natural History.
Belgium, Royal Observatory.
Berlin, International Geodetic Association.
Berlin, Physical Society.
Berlin, Royal Astronomical Institute of Computation.
Berlin, Royal Observatory.
Berlin, Royal Prussian Academy of Sciences.
Berne University.
Bombay Branch of the Royal Asiatic Society.
Bombay Government Observatory.
Bonn, Royal Observatory.
Bordeaux Observatory.
Boston, American Academy of Arts and Sciences.
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Brussels, Royal Academy of Sciences.
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Buda-Pesth, Royal Hungarian Institute for Meteorology and Terrestrial Magnetism.
Buenos Aires, Argentine Meteorological Office.
Calcutta, Asiatic Society of Bengal.
Calcutta, Surveyor-General of India.
Canada, Geological Survey.
Cape of Good Hope, Royal Observatory.
Cape Town, South African Philosophical Society.
Catania Observatory.
Cherbourg, National Society of Sciences.
Chicago, Academy of Sciences.
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Cordoba, Argentine National Observatory.
Cracow, Academy of Sciences.
Delft, Polytechnic School.
Dijon, Academy of Sciences.
Geneva Observatory.
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Helsingfors, Society of Sciences of Finland.
Hong Kong Observatory.
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Lick Observatory.
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Madrid, Royal Academy of Sciences.
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Munich, Royal Bavarian Academy of Sciences.
Naples, Academy of Physical and Mathematical Sciences.
Natal Observatory.
Nice Observatory.
O-Gyalla, Central Meteorological and Magnetical Observatory.
Paris, Academy of Sciences.
Paris, Astronomical Society of France.
Paris, Bureau of Longitude.
Paris, General Depôt of Marine.
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Paris, Mathematical Society of France.
Paris Observatory.
Philadelphia, American Philosophical Society.
Philadelphia, Franklin Institute.
Pola, Meteorological and Magnetical Observatory.
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Pulkowa Observatory.
Rio de Janeiro Observatory.
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Rome, Italian Spectroscopic Society.
Rome, Pontifical Academy *dei Lincei*.
Rome, Royal Academy *dei Lincei*.
St. Petersburg, Astronomical Society of Russia.
St. Petersburg, Astronomical Observatory of the Imperial University.
St. Petersburg, Imperial Academy of Sciences.
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Toronto, Royal Society of Canada.
Toulouse, Geographical Society.
Turin, Royal Academy of Sciences.
Upsal Observatory.
Upsal, Royal Society of Sciences.
Vienna, Austrian Geodetic Bureau.
Vienna, Imperial Academy of Sciences.
Vienna, Imperial Ministry of Marine.
Vizagapatam, G. V. Juggarow Observatory.
Washburn Observatory of the University of Wisconsin.
Washington, Office of the American Ephemeris.
Washington, Philosophical Society.
Washington, Smithsonian Institution.
Washington, United States Coast and Geodetic Survey.
Yale University Astronomical Observatory.
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Zurich, Natural History Society.
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Editors of the "American Journal of Science."
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LITERARY SOCIETY

ADDRESS

Delivered by the President, Sir Robert S. Ball, LL.D., F.R.S., on presenting the Gold Medal to Mr. W. F. Denning.

It is the duty of your President at this annual meeting of our Society to address you on a very important subject. I allude of course to the award of the Gold Medal which is annually conferred by the Royal Astronomical Society on some astronomer who has rendered signal service to our science. The discharge of that duty is perhaps the most responsible official act which devolves on the occupant of this chair, during his tenure of the distinguished position of President. I am to set forth the grounds upon which on the present occasion the medal has been awarded by your Council to our distinguished Fellow Mr. W. F. Denning.

At an early age Mr. Denning manifested that taste for the study of Natural Science, which by diligent cultivation has in due course led him to make those discoveries which we now propose to honour by the highest means in our power. In his boyhood, it was natural history in the study of field life to which, like many another illustrious man of science, he was specially attracted. But the 'stars which in Earth's firmament do shine,' though the stars of his first love, were not the stars by which he was destined to advance to fame. In 1865 Mr. Denning, being then a youth of 17, directed his attention to astronomy, and in the following year he became the possessor of a telescope of three inches aperture.

Stimulated by the views of the celestial glories offered him by this little instrument, Mr. Denning became, as does always the zealous observer, eager to increase the optical powers at his disposal. For a short time he pursued his observations with a $4\frac{1}{4}$-inch reflector, but this again only quickened his desire to have still greater aperture. His wishes in this direction were at last gratified, when in 1870 he purchased a $10\frac{1}{4}$-inch reflector by Browning. It is with this instrument that Mr. Denning's telescopic work, which we are presently to notice, has been chiefly done.

The contributions of Mr. Denning to astronomy may be conveniently ranged under three heads :—

1. *Discovery of Comets.*
2. *Observation of Planetary Phenomena.*
3. *Researches on Luminous Meteors.*

It will be convenient for me to describe his work in these three different departments, taking them in the order just given.

The first and second departments must, however, be treated with comparative brevity, for in making their award your Council have laid special stress on Mr. Denning's Researches on Luminous Meteors.

1. *Comets.*

Each year usually brings the announcement of certain new comets. The discovery of such objects falls to those observers who patiently scan the heavens evening after evening, and morning after morning, with the particular object of detecting these shy visitors to our skies. Mr. Denning has been one of those who have engaged in this work, and his success has been noteworthy. The following list gives the designations of five comets which have been discovered by our medallist.

Comet 1881 V. Period 8·68 years.
„ 1890 VI.
„ 1891 I.
„ 1892 II.
„ 1894 I. Period 7·3 years.

I think it will materially enhance our appreciation of Mr. Denning's perseverance and skill if we note the unique position which he occupies among astronomers in England, so far as the discovery of comets is concerned. Since the days of Caroline Herschel, the only comets, beside those just mentioned, which have been discovered in this country have been those which were detected by Hind and the remarkable object which was found by Mr. Holmes.

While searching the skies for comets Mr. Denning has not unfrequently discovered nebulæ which had escaped the attention of previous observers. No fewer than twenty-one nebulæ have thus been added by Mr. Denning to the lists of those already known. Most of these new objects lie in the vicinity of the North Pole.

2. *Planetary Observations.*

A striking characteristic of Mr. Denning's work is the methodical accuracy with which he has carried through whatever astronomical research he had in hand. Mr. Denning never spared

himself any pains in the efforts necessary to give his work the inestimable charms of thoroughness and precision. This may well be illustrated by his work on *Jupiter*. It is well-known that this very difficult object not only demands instruments of much optical perfection, but also calls for the exercise of the highest qualities which constitute a consummate astronomical observer. Mr. Denning made admirable sketches of the planet, in which he represented a remarkable amount of detail with a skilful pencil. But he was not content with artistic work merely, however valuable such work may be; he patiently watched the revolutions of a large number of spots on *Jupiter*, and determined as accurately as possible their times of transit over the central meridian of the planet. By such observations he ascertained the periods of rotation of a large number of particularly well marked spots. Thus he illustrated the instructive fact that individual spots are animated by large proper motions on the surface of the planet. The famous red spot so well known to every astronomer has been in particular most diligently followed by Mr. Denning. He has demonstrated the remarkable circumstance that the period in which it returns to the central meridian of the planet varies from year to year. The results at which he has thus arrived are in close accordance with the observations of other accomplished astronomers.

3. *Researches on Luminous Meteors.*

The great work of Mr. Denning's scientific career, and that which has been mainly instrumental in deciding your Council to confer on him the distinction of the Gold Medal, has been devoted to the very important subject of luminous meteors. The labours of Mr. Denning have been so extensive (and they cover nearly every branch of the subject of meteorological astronomy), that it would be difficult—indeed, I may say it would be impossible—to render any adequate account of it within the limits of an address; I am therefore obliged to restrict myself to those more salient points which have specially influenced the decision of your Council.

The papers on luminous meteors communicated to the Royal Astronomical Society by Mr. Denning, and printed in the *Monthly Notices*, number altogether forty-two. In bulk they would, if collected together, constitute two-thirds of an ordinary annual volume in that form of the Society's publication. These papers are illustrated with graphic and instructive figures much more copiously than has usually been the custom in communications of this class.

A considerable number of these memoirs contain valuable lists of meteoric radiants, derived either exclusively from Mr. Denning's own work at Bristol or from his own observations in connection with the work of other astronomers in the same field.

Mr. Denning's first published list of radiants appeared in 1876. It contains the determinations of twenty-seven radiant points derived from his own observations of nearly nine hundred meteor tracks which he had himself mapped at Bristol between 1871–6. In this early list the periods of the recurrence of the showers are occasionally indicated by single days or short periods, but usually the month of recurrence is alone given. The list contains careful determinations of the radiant points of the chief annual showers, such as *Quarantids* in 1873, the *Lyrids* in 1873 and 1874, the *Perseids* in 1871 and 1874, the *Orionids* in 1874, and the *Andromedids* in 1872. It is interesting to note that to all but four of the radiants in the list corresponding showers were found in Mr. Greg's first general star shower catalogue. This was published in comparison with Dr. Heis' and other well-known contemporary radiant-lists, in the British Association volume of *Reports* for the year 1874. The four radiants which Mr. Denning did not find corroborated in that general catalogue, are all, it ought to be observed, marked as doubtful ones in this early list.

The latest list of radiants which has been issued by Mr. Denning, and the longest paper that he has as yet communicated to the *Monthly Notices*, was published in 1890. This important work gives remarkable evidence of the diligence of our medallist. It contains a list of 918 radiant points, deduced from the observations of no fewer than 9177 meteors, mapped at Bristol between the years 1873 and 1889. This list, it should be remarked, includes repeated observations of the same radiants. This is the case, not only with regard to the chief showers, but also with regard to various minor showers whose yearly dates of recurrence cannot in the present state of our knowledge be assigned with any certainty.

Though many of these showers are but sparsely characterised by meteors—or, to use the more technical expression, are showers of great tenuity, they have not escaped the persistent scrutiny of Mr. Denning. In such cases the dates, are generally assigned to single days when the meteors have apparently maximum abundance. A column of supplementary dates, which seldom range over more than a week, has been added. It will thus be seen that this catalogue presents an extensive series, not so much of averaged results, as of exact and valuable individual determinations.

In other papers by Mr. Denning mean results have been given which may be regarded as summarising the present state of our knowledge with regard to many important showers. For the chief meteoric showers a list of this kind was published in 1888. In it will be found mean positions for 1880 derived from fifteen years of observations of the radiant points of the nine chief yearly showers. These contain the seven well-known periodic swarms of January, April, August, October, November (two showers), and December, adding to these the striking and

very regularly visible displays of May 6 and July 28. A very useful list of 35 radiants is given by Mr. Denning in the *Admiralty Manual of Scientific Inquiry* (5th edition), 1886.

As an illustration of the perseverance and skill which has been shown by Mr. Denning in the determination of the positions of the radiants, I may mention the following circumstances with respect to the radiants of the *Lyrids*. In 1867 the April meteors were shown by Galle and Weiss to present a similarity of orbit to that of Comet 1, 1861. Weiss gave the cometary radiant as R.A. 270°·4, Decl. +33°·5, while Professor Herschel afterwards computed it as R.A. 270°·5 and Decl. +32°. The meteoric radiant was at R.A. 278°·2, Decl. +34°·5 (Galle and Karlinski), at R.A. 277°·5, Decl. +34°·5 (Greg and Herschel), at R.A. 277°, Decl. +38° (Heis), and at R.A. 267°, Decl. +35° (Serpieri). These positions gave a mean radiant a few degrees N.E. of the calculated radiant of the comet, and this discrepancy rendered the supposed identity of the meteors with the comet somewhat questionable. In 1873 and 1874 Mr. Denning watched the April meteors, but his observations were not very complete at that period, and he found the radiant at R.A. 274°, Decl. +37°. In 1878 and later years, having gained the experience necessary in critical meteoric work, he redetermined the radiant and found it practically identical with that computed from the cometary orbit. His positions were :—

	R.A.	Decl.		
1878 April 20–21	272°	+32°	10	meteors
1879 April 20	272°	+33°	8	„
1884 April 19	269°	+33°	17	„
1885 April 19–20	271°	+33°	24	„
1887 April 19–20	270°	+32°	11	„
1893 April 20–21	272½°	+33½°	15	„

The detailed accounts of Mr. Denning's observations of many special meteor showers constitute several of his most valuable papers. The first paper that he ever communicated to the Royal Astronomical Society related to the famous shower in 1872. I dare say many of those present will recollect, as I do myself, that beautiful display of the *Andromedids*. It may be noted, as a matter of interest on the present occasion, that this memorable night may also be said to coincide with the commencement of Mr. Denning's career in connection with our Society. But he has put it on record that he commenced to observe meteors some years earlier, on the occasion of the ever memorable display of the *Leonids* in 1866.

In this earlier paper Mr. Denning tells us, among other interesting matters, how he made his observations of the *Andromedids* in 1872. Watching with one companion between 6 and 6.30 that evening, they enumerated from seventy-five to eighty *Andromedids*, and only one unconformable meteor was noticed. Of

the meteors they saw about ten or fifteen were at least of the first magnitude, and as the rest were bright enough to be seen in the hazy sky, they must have been of about the second magnitude. From the many tracks that were mapped down, as well as from some stationary meteors which were also noticed, the radiant point was found very well defined, and was located at R.A. 29°, Decl. +46°, about 4° north of γ *Andromedæ*.

With this early work of Mr. Denning's it is interesting to compare the observations that he made of the same shower when in 1885 it had completed two more revolutions. This he describes in the paper communicated that year to the *Monthly Notices*. If I give here an abstract of his observations, it is because I think it is no exaggeration to regard them as a model of the way in which the phenomena of luminous meteors should be watched for, and an instructive lesson as to the points to be specially recorded.

He commenced to watch for the great display of *Andromedids* in partly clouded sky on 1885 November 26. In a clear quarter of an hour, from 8.30 p.m. and later in a few periods, twenty-one and forty-two meteors respectively were counted by Mr. Denning and another observer. It is estimated that they were thus arriving at the rate of about 130 per hour. Of those seen nineteen and forty-one were *Andromedids*, and their radiant region, which was some degrees wide, appeared to have a centre about R.A. 26°, Decl. +44°. From midnight onwards the sky was overcast.

On the following night, 1885 November 27, a rich star shower was observed from twilight until 6.40 p.m., when clouds and rain came on. The number would probably have reached 5000 per hour had the sky been perfectly clear, for 222 were counted through the haze in the last and clearest five minutes, showing themselves in intermitting pulses or volleys of five to ten or more at a time. The radiation was decidedly diffuse, proceeding in a loosely disjointed way from an area fully 7° in diameter about a centre at R.A. 24°, Decl. +44° between γ and ξ *Andromedæ*. Several of the meteors seen on the 26th, and many on the 27th, were as bright as *Jupiter*, indeed some of those on the 27th were brighter than *Venus*. They seemed to be composed of loose materials crumbling away in their flight to spark dust ere they vanished.

A chart of forty-nine *Andromedids* and a list of twenty bright ones are given as observed on the evenings of November 26 and 27, showing the mean radiant-point at R.A. 25°, Decl. +44°.

Forty-five more *Andromedids*, half of them of rather smaller magnitudes, were noted in about four hours—on the evening of November 28, and a chart of their tracks showing a radiant-point at R.A. 22°, Decl. +43½° was also given.

Ten meteors of the same shower were seen on November 30 in 4½ hours, and these were sufficient to give a radiant at R.A. 21°, Decl. +42½° ; but on December 1, 4, and 7, no further symptoms

of the shower were traceable. In its whole duration of fully five days (it lasted very possibly one or two more days, for clouds prevailed at its commencement), the radiant-point was thus observed to recede about five degrees in right ascension.

The rather bright shower from *Andromeda* of forty per hour, which was seen on 1872 November 24, 7.30 to 12 p.m., at Newhaven, Conn., and more faintly on the following night, was certainly not continuous with the grand display of November 27 in the same year. The nights of November 25 and 26 were noted by Mr. Denning, at Bristol, as unsurpassed in November for paucity of meteors.

Another very interesting shower admirably studied by Mr. Denning was that from 1897 April 29 to May 6. Of all the shooting stars appearing through the year, there are none more striking for their long, bright, streak-leaving courses than those which from April 29 to May 6 may be seen after midnight proceeding from that radiant-point at the east horizon, first defined by Colonel Tupman in 1869–70 near α and η *Aquarii*. The orbit of Halley's comet approaches the earth's orbit near the position occupied by the Earth on May 4. The distance is about five and a half million miles on the inner side of the earth's track. The magnitude and brightness of that comet's tail projecting outwards from the Sun suggests the possibility of its connection with this shower. Fragments accompanying the comet would have an apparent radiant-point nearly at η *Aquarii*, but this is 12° E on the equator from the radiant found for the meteor shower by Colonel Tupman.

A trial was made by Mr. Denning to re-determine this star-shower's date and radiant-point exactly, by projecting 229 tracks in April and May from the Italian Meteor Association's Catalogue of about 7600 meteor paths observed in 1868–70. A resulting place at R.A. 335°, Decl. −9° was obtained for the radiant-point. This is considerably southward and eastward from Colonel Tupman's position at R.A. 326°, Decl. $-2\frac{1}{2}°$, but yet does not agree very well with the computed radiant R.A. 337°, Decl. $\pm 0°$ on May 4, of a stream of meteor particles from Halley's comet.

The late hour of the radiant's rising, between 1^h and 2^h a.m., makes a good view of this splendid shower not easy to obtain.

Its centre had been noted by Mr. Corder from observations made in 1876–79, at R A. 334°, Decl.−5°. But the difficult task of carefully re-observing this shower's radiant-centre remained for Mr. Denning to accomplish, and he watched the sky on a succession of clear, moonless nights in April–May 1886, for 27 hours for this purpose, mapping in all 117 meteors in a time of unusual scarcity of shooting-stars, with a perseverance and success perhaps never surpassed in meteor-observations. From nine very accordant tracks of the beautifully long-pathed Aquarid meteors seen between April 30 and May 6, most abundantly on the latter date, and from three others which only

deviated a few degrees from the position, the centre of the shower was found, with only slight diffuseness, to be at R.A. 337°, Decl. $-2\frac{1}{2}°$; all doubt of its agreement in place and date with the time and radiant-point of a shower connected closely in some way with the orbit of Halley's comet being thus clearly shown to be unfounded.

In the *Monthly Notices* for 1894 June, Mr. Denning sums up his extensive experience on the questions of the general directions of great fireballs, and of the brighter shooting stars as compared with those of ordinary shooting stars. He tells us that the striking objects commonly diverge from radiant-points at places in the western or anti-apical half of the sky, quite remote from the radiant-points of contemporaneous meteor showers. This noteworthy result is arrived at not only from most of Mr. Denning's own determinations of the real paths of such meteors, but from a numerous collection of published determinations of these paths which he has brought together for comparison with his own results.

This singularity of direction, for so it at first appeared, seems now to be a regular feature of the usual movements of fireballs. That a great fireball, leisurely streaming across the sky, should come from a westerly direction, is quite a normal circumstance; a movement in this direction is, however, rarely seen in the case of ordinary shooting stars.

Although a connection between a fireball and some weak contemporaneous shower may now and then be perhaps traced, yet many fireballs seem to be so isolated that Mr. Denning has been led to suspect that they "must either be merely single sporadic bodies, or else the survivors from some meteor group nearly exhausted by the waste of its material during many past ages."

In a weighty concluding paragraph touching the question of the similarity or the diversity of origin of meteorites, fireballs, and shooting stars, Mr. Denning quotes the late Professor H. A. Newton's striking conclusion from his study of observed paths of meteorites. It appears that, out of 116 stone falls investigated by the diligent American astronomer, 109 must have been overtaking the Earth, and only seven seem to have met the Earth. He infers from this that nearly all the stones in the Solar System move in direct orbits.

As an illustration of the thoroughness of the work of Mr. Denning in the interesting problem of the determination of the path of a fireball, we may consider the remarkable object which appeared at ten o'clock on the evening of 1894 January 25. This was a large detonating fireball which, in a generally clouded sky, is stated to have illuminated the north-western parts of England as brightly as the full Moon is able to do. It disappeared at the end of a long obliquely-descending course from N.W. to S.E. at a height of sixteen miles over a point three or four miles east from Tewkesbury. At Malvern and Worcester,

on either side of the end of its track, as well as at other places, a violent explosion was heard which resembled a clap of thunder. The report reached Malvern after an interval of about three minutes, corresponding to a distance of 37 miles. Various other incidents of the explosion have been also collected from different sources.

Mr. Denning carefully sifted more than forty accounts of the occurrence collected from different English and Welsh localities. Those which were found to be available for the actual determination of the path of the fireball were the observations near Lancaster by Mr. Clapham, near Birmingham by Messrs. Packer and W. H. Wood, at Sunderland by Mr. Backhouse, and by Mr. Denning himself at Bristol. The visible extent of the meteor's real path thus obtained was found to be about 160 miles, which was traversed in about 9 seconds. Its course began 89 miles high over the Irish Sea, 24 miles N.N.E. from Amlwch, in Anglesey, and passing at heights of 45 and 22 miles nearly over Shrewsbury and Worcester to the above-named terminal point.

The direction of flight was from near ϵ *Cephei*, a place not known previously as a radiant-point of shooting stars so late in winter, although a centre near this was found on 1886 January 4–8 by Mr. Denning, and though in summer and in autumn months radiant-points in the same quarter are numerous. This point is, in fact, one of those enumerated in the list of 45 stationary radiant-points at the end of Mr. Denning's list of 918 radiant-points. It is noted as having been seen with very prolonged duration from June to December in the fine summer months of 1887. The parabolic meteor speed corresponding to this deduced radiant-point is $13\frac{3}{4}$ miles per second, while the observed velocity was 18 miles per second.

The most important contributions which Mr. Denning has made to the general problems connected with luminous meteors are undoubtedly connected with the long duration of meteoric radiants. The fact of long persistency of radiant-points, and of close assemblages about the points, of groups or compact families of simultaneous or successive meteor streams is as old as Heis' first essays in meteor showers. It is, however, to Mr. Denning's inquiries that we are indebted for our knowledge of this subject. In his important paper of 1884 December, Mr. Denning writes: "The fact of stationary radiants exhibiting visible activity during several months is a phenomenon so unaccountable and so utterly opposed to the approved theories as to the orbits of shooting stars that it must receive a most crucial examination before it can be accepted."

The long-continued labours of Mr. Denning on this important subject have demonstrated the existence of these enduring radiants. The theoretical difficulties connected with the subject may be still not altogether removed, but we can hardly refuse assent to Mr. Denning's words when he says: "It must be conceived that a well-attested fact of observation, however hard to

reconcile with known theories, ought on no account to be disregarded on account of its nonconformity."

It is, of course, known that the *Perseids* of the August meteor-shower are found, not only on the special nights with which the swarm is chiefly associated; they are also displayed on many preceding and following nights. Mr. Denning has traced meteors of this group for the twenty-six nights from July 25 to August 19, and their radiant advanced in that interval over a distance of forty degrees. In one of those admirable diagrams by which the interest of Mr. Denning's papers is so greatly increased, he gives a curve of the ordinary number of *Perseids*, rising from one on July 25 to a maximum of fifty-seven on August 10, and then declining to one on August 19. In his paper of 1890 Mr. Denning shows that the range of the *Perseids* is even wider still. I cite this case of the *Perseids*, because the gradual shift of the radiants, as days and weeks pass by, is of course no more than should be expected from the change of the place of the Earth in its orbit. The extraordinary fact is that in the case of certain other showers, which are visible for weeks or months, the radiant undergoes no appreciable change in position.

The six showers that Mr. Denning specially selects for discussion in his memorable paper of 1884, are as follows; we direct special attention to these results, because they may be regarded as the authoritative announcement of the important discovery under consideration.

	Radiant.		Apparent Duration.	Shower.	Positions Averaged.
	R.A.	Decl.			
	°	°			
I.	30·0	+36·0	July 16–Nov. 14	β Triangulids	23
II.	46·0	+45·6	July 6–Nov. 30	$\alpha-\beta$ Perseids	31
III.	61·0	+47·7	July 25–Nov. 27	μ Perseids	21
IV.	61·8	+36·8	Aug. 2–Dec. 31	ϵ Perseids	26
V.	76·2	+32·6	July 23–Dec. 27	ι Aurigids	21
VI.	80·2	+22·9	Aug. 24–Jan. 15	ζ Taurids	25

Taking the second of these showers as an example, we have fifteen determinations of the radiant II., by Mr. Denning himself, extending from July 6 to November 14. The mean of that concordant series of determinations places the radiant at R.A. 46°·1 and Decl. +45°·0.

Then follow sixteen determinations of the radiant by other skilled observers of meteors, Schmidt, Tupman, Schiaparelli and Zezioli, Maggi, Heis, Corder, Sawyer, Greg, and Herschel. Here again we have another series of results extending from August 3 to November 30, placing the mean radiant at R.A. 45°·8, Decl. +46°·2. It is impossible to resist the logic of these facts; whatever may be their explanation, the existence of the enduring radiants must be admitted.

Such a paper as that which I am now referring to must be regarded as a classic which everyone who desires to devote himself to the fascinating subject of meteors would do well to study. It is full of interesting facts and suggestion. We learn that in the catalogues published up to this date there are no fewer than 2100 radiants resulting from the projected paths of upwards of 62,000 meteors ; many of these are known duplicate observations of identical streams, and Mr. Denning adds that he does not believe the total number of well defined streams would exceed 350.

Mr. Denning has given in the introduction to his great catalogue of 1890 a very interesting general statement of his methods of work.

"My plan of working may be briefly described as follows :— All the observations were made in the open air, and from the garden adjoining the house. Attention was almost invariably given to the eastern sky. In mild weather I sat in a chair with the back inclined at a suitable angle ; but on cold, frosty nights I find it expedient to maintain a standing posture, and sometimes to pace to and fro, always, however, keeping the eye directed towards the firmament in quest of meteors."

"I find it essential to rely on the latter instrument (a perfectly straight wand) as a help and corrective to the eye in ascribing the lines of flight. When a meteor was seen the wand was immediately projected upon its track and the position quickly noted and reproduced on an 18-inch celestial globe. The time, magnitude, appearance, beginning-point and probable radiant were then written down, and other details left to be filled in on the following day, when all the paths were carefully compared and their provisional radiants derived."

Mr. Denning points out that in open country places the mean horary number of meteors is 11·4. The average lengths of the paths of all the meteors he has observed is 10°, and the maximum number of meteors is attained between 2 and 3 a.m., when the rate is nearly double that in the early hour of the evening.

On the important subject of stationary radiants additional information has been acquired during the five years following the important statement of 1884. It has been tested by about 5000 observations made since that time, and the new materials certainly seem to corroborate the conclusion already arrived at. Mr. Denning here again refers to the remarkably long enduring shower between α and β *Persei*. He has obtained several fresh determinations of it, and he gives it as one of the best instances of an apparently stationary radiant. The following is the remarkable table referred to :—

Long enduring shower between α and β Persei.

		R.A.	Decl.			R.A.	Decl.
		°	°			h	°
1877	July 20	47	+45	1885	Sept. 15	48	+43
1884	July 23–25	48	+43	1877	Sept. 15–16	47	+45
1886	Aug. 2–10	48	+43	1886	Sept. 22–30	48	+44
1888	Aug. 5–14	48	+44	1887	Oct. 17–24	47	+44
1877	Aug. 3–16	46	+45	1879	Oct. 20	45	+46
1884	Aug. 19–21	46	+44	1879	Nov. 12–14	48	+43
1879	Aug. 21–23	46	+47	1877–86	Nov. 27–Dec. 8	48	+42
1887	Aug. 30	46	+43	1886–8	Dec. 28–Jan. 11	47	+44
1887	Sept. 12–24	47	+43	1876–87	Feb. 23–Mar. 12	47	+45

Mr. Denning has recently published in the *Observatory* an instructive and opportune series of papers on the expected great showers of *Leonids* in the next few years. This subject is here discussed with that wealth of knowledge and experience which characterises all Mr. Denning's contributions. He commences these papers with the words :

"It may safely be said that in the month of November during the next few years, all astronomers and a large majority of the general public will become meteoric observers, for the phenomena presented will be of an exceptional kind, and of a character to interest everyone."

We all echo these remarks. I think I am justified in adding that much of the recently-awakened interest in the subject has been due to the worthy example Mr. Denning has himself given us. Who among us would not be proud to imitate his single-hearted and enthusiastic devotion to the discovery of truth in this beautiful department of astronomy ?

It is a matter of great regret to everyone here assembled that our medallist, whom we so greatly wish to honour, is not now present in person to accept our award. We regret this all the more when we learn that ill health is the cause of his absence. We unite in expressing a hearty wish for his speedy recovery. We assure him not only of our appreciation of his admirable work, but of the high esteem which we personally entertain for him. On your behalf, therefore, I now hand the Gold Medal of the Royal Astronomical Society to our Secretary, to be by him transmitted to Mr. W. F. Denning in recognition of the valuable services to our science which he has rendered, especially in the department of meteoric astronomy.

The meeting then proceeded to the election of the Officers and Council for the ensuing year, when the following Fellows were elected :

President.

Sir R. S. Ball, M.A., LL.D., F.R.S., Lowndean Professor of Astronomy and Geometry, Cambridge.

Vice-Presidents.

Capt. W. de W. Abney, C.B., R.E., D.C.L., F.R.S.
W. H. M. Christie, Esq., C.B., M.A., F.R.S., Astronomer Royal.
A. A. Common, Esq., LL.D., F.R.S.
J. W. L. Glaisher, Esq., M.A., Sc.D., F.R.S.

Treasurer.

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A. M. W. Downing, Esq., M.A., D.Sc., F.R.S., Superintendent of the *Nautical Almanac*.
F. W. Dyson, Esq., M.A.
Capt. E. H. Hills, R.E.
Major P. A. MacMahon, R.A., D.Sc., F.R.S.
W. H. Maw, Esq.
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A. A. Rambaut, Esq., D.Sc., Radcliffe Observer.
G. M. Seabroke, Esq.
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